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THESIS

DESIGN OF THE DIGITAL SATELLITE LINK INTERFACE FOR A SYSTEM THAT DETECTS THE PRECURSORY ELECTROMAGNETIC EMISSIONS ASSOCIATED WITH EARTHQUAKES

by

Kevin C. Ebel
December 1986

Thesis Advisor: R. W. Adler

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The design, construction and implementation of a computer controlled radio frequency (RF) noise measurement and recording system in the 30.45 MHz and 150.MHz range and the interfacing of this system to a digital satellite link is presented. Earthquake prediction by the use of various physical precursors and the specific use of electromagnetic emissions in the RF range as a precursor to future earthquake activity is described.

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Design of the Digital Satellite Link Interface for a System that Detects the Precursory Electromagnetic Emissions Associated With Earthquakes

by

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Lieutenant, United States Navy
B.S., University of Florida, 1977

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The design, construction and implementation of a computer controlled radio frequency (RF) noise measurement and recording system in the 30.45 MHz and 150.75 MHz range and the interfacing of this system to a digital satellite link is presented. Earthquake prediction by the use of various precursors and the specific use of electromagnetic emissions in the RF range as a precursor to future earthquake activity is described.

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I. INTRODUCTION

A. THE NEED FOR EARTHQUAKE PREDICTION RESEARCH

Intensive academic and social attention has been drawn to earthquake prediction, especially in countries like Japan, the United States, China and the Soviet Union which have all suffered from very destructive earthquakes on numerous occasions. Investigation into the realm of earthquake prediction in these countries has brought out clues pointing to the fact that the prediction of some earthquakes, if not all of them, will be attainable in the foreseeable future. Of course, all of the permanent measures that are used to reduce earthquake hazards, such as better engineering design, improved land use planning, and upgraded building codes and construction practices will continue to be needed even though earthquake predictions may eventually become completely reliable. The benefits to society from accurate earthquake prediction will be substantial in the savings of lives and property.

It has been estimated that the knowledge of an impending great earthquake a year or more in advance would result in a large reduction in losses. The savings would result from measures taken to strengthen buildings and their contents, reduce fire hazards, increase dam safety, enhance nuclear power plant safety and so on. For shorter term predictions such as a week in advance, substantial savings of lives would result from temporary measures such as the evacuation of dangerous buildings and the mobilization of emergency forces. [Ref. 1:pp. 35-45]

It is known in many instances that the earthquake itself will cause less damage and casualty than the events which occur following the actual geophysical phenomena. Fires and explosions resulting from ruptured gas lines, gasoline storage tanks, power lines and transformers will contribute to the severe loss of life and property. If the utilities such as gas and electricity were to be equipped with sensing devices which would automatically interrupt services when precursory information was acquired concerning a potential earthquake, great devastation could be spared. If the ability to predict an earthquake could be soundly established, a more calculated reaction to the event could be made. Evacuation of endangered areas, or even the planned demolition in advance of structures deemed unsafe in the event of a major temblor could be accomplished. Unfortunately, the ability to accurately and reliably predict the location and intensity of a forthcoming earthquake is unavailable at the present time.

Great excitement currently exists among seismologists over major achievements in the effort to predict earthquakes. Various physical phenomena precursory to earthquakes have been reported. Measurable physical precursors are now coming under intense scientific scrutiny and many appear to be valid. Several scientific predictions have already been successful, although they were for smaller scale earthquakes [Ref. 2]. Few seismologists now doubt that physical precursors to earthquakes do in fact exist. However, the ability to be sufficiently consistent and uniform enough to permit development of a routine and reliable prediction system does not exist.

B. RESEARCH PROJECT BACKGROUND

This thesis advances the previous research into the evidence of radio frequency (RF) emissions as a precursor to earthquake activity. Citizen band and amateur radio operators in the Hollister, California area have reported an "increase in the background noise level preceding earthquake activity" at 27 MHz and at the six and two meter bands. The increase in noise was on the order of 10 dB and preceeded a quake by 12 to 24 hours. At one hour to fifteen minutes prior to an actual earthquake, noise levels returned to normal [Ref. 3:p. 11]. The appearance of a phenomena known as earthquake lights

[Ref. 4] and the reception of 18 MHz radio noise [Ref. 5] are further examples of the potential link between RF energy and the occurrence of earthquakes. Further presentation of measured precursory events and the associated theories to explain them are presented later in this thesis.

The design of a freestanding VHF noise measurement and recording system to predict the intensity and location of earthquakes from electromagnetic radiation at an active geophysical location along the San Andreas Rift Zone (fault) was initiated in 1984 [Ref. 6] by a joint project of the U.S. Geological Survey Office and the Naval Postgraduate School. The following year the proposed design of a space based sensor to predict the intensity and location of earthquakes from electromagnetic emissions was completed and the initial installation of the noise measurement and recording system was made [Ref. 3]. It is at this point that the endeavors of this thesis begin.

The data acquired from the VHF noise measurement system was observed for background noise level variations. Seismological data acquired from the Geological Survey Office was compared to the data obtained on the chart recorder paper. In order to accurately correlate the data it was necessary to manually measure the magnitude of the VHF signal at predetermined time intervals off of the chart recordings, then enter these readings into a computer for future graphical display. This process of digitizing the data every two weeks for the recordings of ten separate channels of information stored on very lengthy rolls of chart recorder paper is extremely time consuming. An example of some of the first data retrieved from the chart paper is shown in Figure 1.1. Each of the plots represent two weeks of data for one specific channel. Approximately six man hours were used to obtain these graphs.

A solution to reducing the amount of time required to analyze the collected data, as well as obtaining a means of transmitting this data over a digital satellite link was being sought after by the U.S. Geological Survey Office. A monitoring system in the Parkfield, California area relying on the phone system for the transmission of data had lost vital information during an actual earthquake.

C. FOCUS OF STUDY

In order to fulfill the need for an accurate and reliable radio frequency noise measurement and recording system for detection on the 30 MHz and 150 MHz bands which provides the means for rapid data acquisition and analysis, the design of a computer controlled monitoring

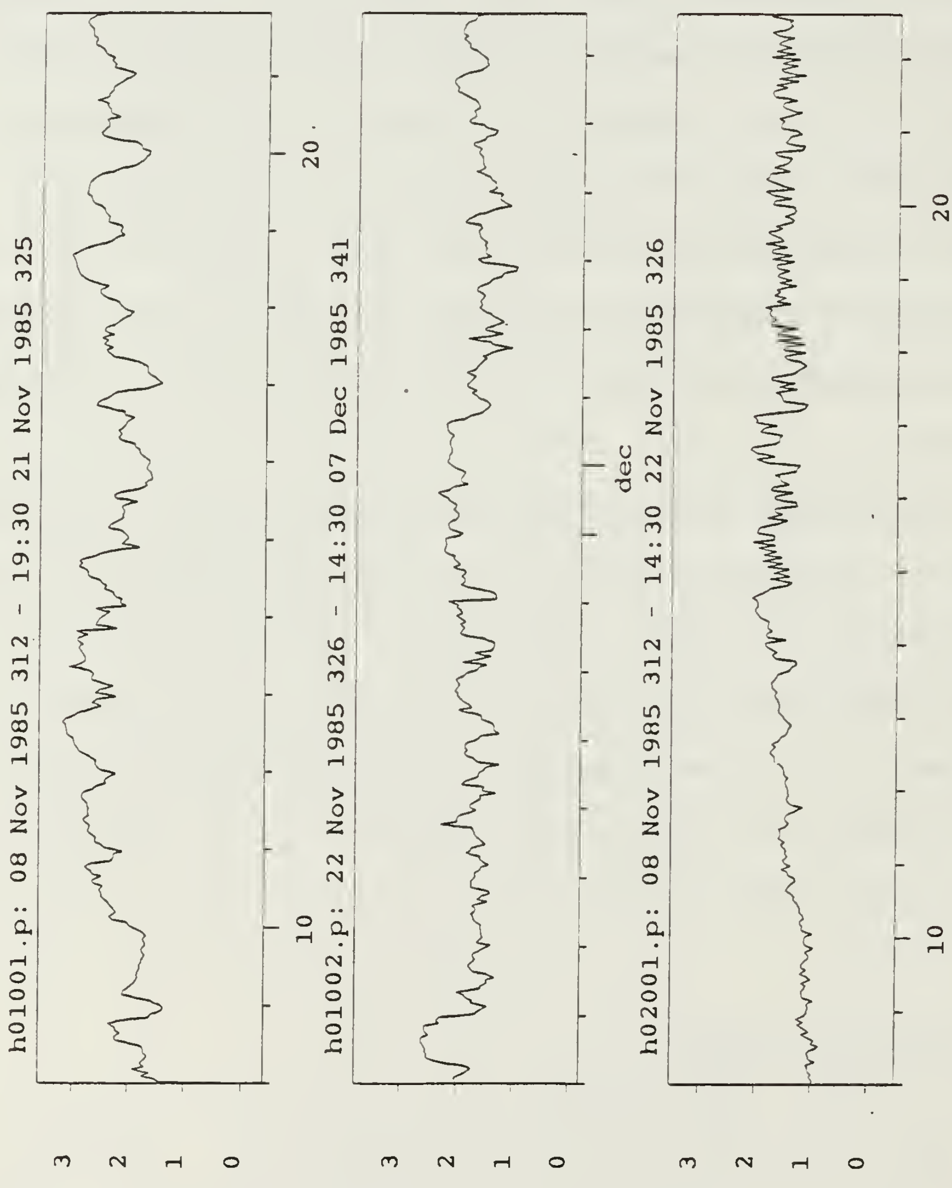


Figure 1.1 Collected Data for November/December 1985

system is presented. Initially the data is stored on magnetic disk to allow for a series of software routines to graphically display the data. In addition, the need for a survivable remote sensing capability is fulfilled by the design of digital satellite link interface. The data may be sent from the constructed computer monitoring system to a Data Collection Platform Radio Set (D.C.P.R.S.) for transmission via the Geostationary Operational Environmental Satellite (G.O.E.S.) transponder to the Command and Data Acquisition Station in Wallops Station, Virginia. The establishment of a correlation between increased background RF noise to future earthquake fault activity may be accomplished as a result of the improved data analysis capability.

II. BACKGROUND

A. STRUCTURES OF EARTHQUAKE PREDICTION

A successful prediction must include the correct assessment of three elementary factors, namely the time, place and size of the predicted earthquake. In order to approach this goal, a prediction should develop systematically through the stages shown in Figure 2.1 [Ref. 7:p. 195]. The size of the various rectangles shown in the diagram represent the relative degrees of uncertainty in the different types of prediction. A discussion of the various realms of the prediction process follows.

1. Statistical Prediction

The first stage of earthquake prediction called statistical prediction, is based on the assumption that earthquakes occur in a sequence with a statistical characteristic which does not change with time. If the sequence of the earthquakes has either a predominant period or a probable correlation to a known external factor, then the future activity may be predicted statistically. However, the prediction will involve a considerable degree of uncertainty. This type of broad scale prediction is satisfactory for preliminary work such as in long-term planning of optimum monitoring systems and disaster prevention work.[Ref. 7:p. 194]

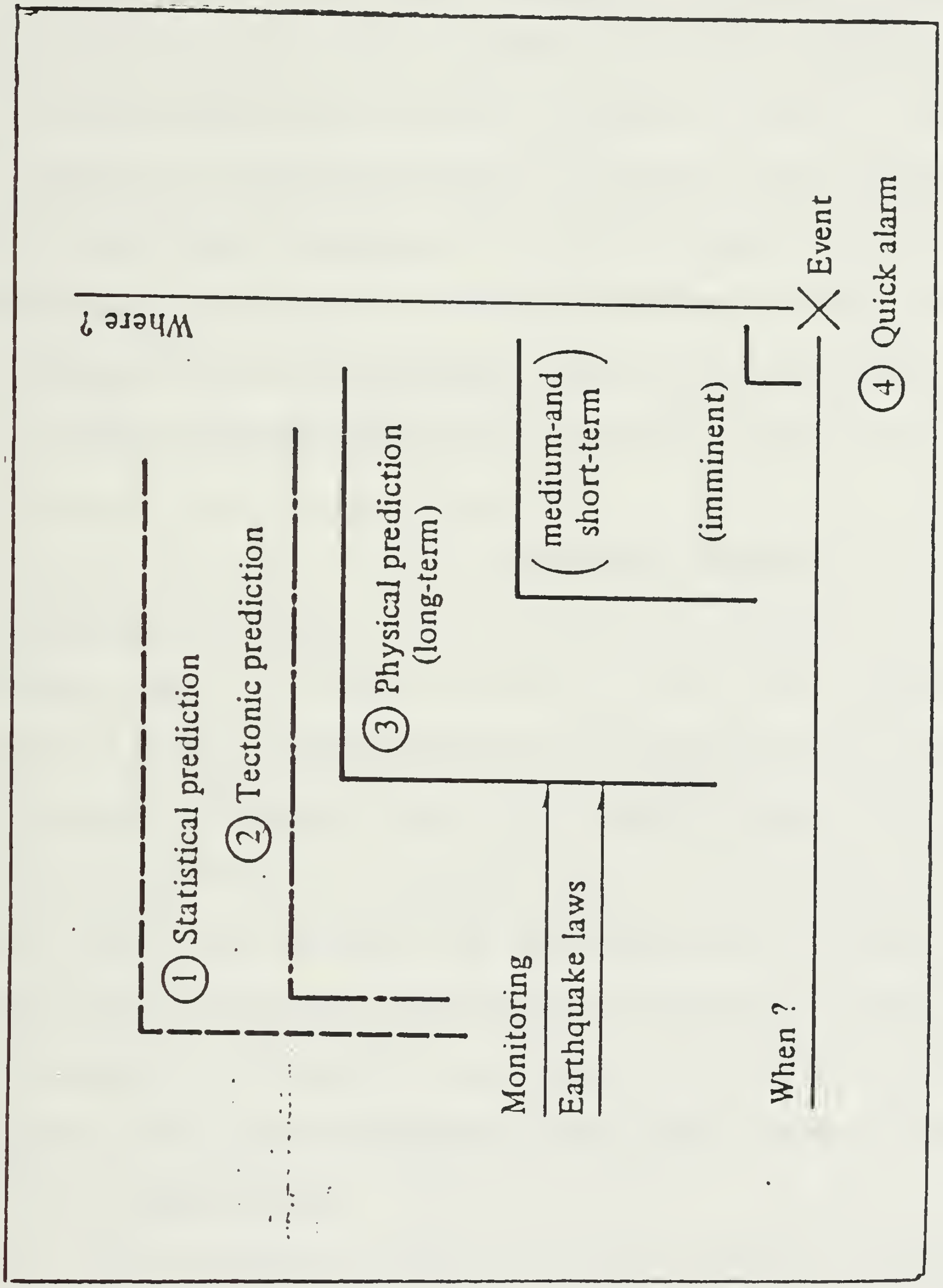


Figure 2.1 Stages of Earthquake Prediction

2. Tectonic Prediction

This type of prediction is primarily concerned with the magnitude, type and other tectonic parameters of an earthquake that is likely to occur in a given locality [Ref. 8:p. 1082]. The accumulation law of seismotectonic movement relates the amount of accumulated strain and stress across a fault to the potential for the occurrence of an earthquake. This type of prediction will provide a mean lapse time for the seismic cycle, but precise time information is not available [Ref. 7:p. 195].

3. Physical Prediction

Physical prediction attempts to precisely determine the three critical factors of time, place and size by the recognition of meaningful seismic precursors to major earthquakes. It is an essential requirement that a sufficient understanding of the physical laws of earthquakes be available and precise monitoring of the area in and around an earthquake be made at the proper time. Preseismic anamolies have been noticed in the study of many other geophysical phenomena [Ref. 9]. In addition to the extraordinary behavior of fish and animals, there is an extensive set of precursors experienced at various times and in various regions of the world of the following types:

- land deformation
- tilt and strain
- foreshock
- microseismicity
- source mechanism
- fault creep anomaly
- seismic wave velocity
- geomagnetic field
- telluric (earth) currents
- electromagnetic emissions
- resistivity of the earth
- radon content
- underground water
- oil flow

An in depth discussion of the shock wave theory of radio emissions from earthquake fault lines is presented, as this is the focal point of the thesis. The design and construction of the computer controlled VHF radio noise measurement and recording system is based on the concept of using electromagnetic emissions as a precursor to future earthquake activity.

4. Quick Alarm

In strictest terms this last stage is not really prediction, but actually a method of practical disaster reduction. This stage relies upon a fully-automated monitoring system which is linked to critical public and/or industrial facilities so that they may be controlled promptly in an emergency. If the system detects and recognizes an imminent seismic event, the critical facilities such as the utilities of gas and electricity could be secured before the main seismic disturbance strikes.[Ref. 7:p. 196]

Practical earthquake prediction may eventually be accomplished by analyzing the accumulated predictions of each of the four stages. The successful use of these predictions in an orchestrated effort to accurately and reliably predict earthquakes is in the foreseeable future.

B. RADIO FREQUENCY EMISSIONS

This thesis investigates the potential of using electromagnetic emissions in the radio frequency range as a precursor to earthquake activity. Radio frequency emissions from active earthquake fault lines have been reported by radio amateurs in the HF and VHF band of frequencies. The emissions are theorized to be caused by the increasing mechanical pressure at the fault causing sheer stresses that convert the insulating rock into a conductor (or semi-conductor) by reducing the energy gap between the valence and conduction bands. During the stress increase, microfractures cause shock waves that accelerate the electrons in the conducting bands to radiate both acoustic and electromagnetic energy. If the mechanial forces increase to the yield point, the rock fails in brittle fracture and causes a sudden decrease in the shear forces resulting in electron accelerations that produce either large increases in radio noise, or in the phenomena known as clear weather lightning.[Ref. 10: p. 1]

The initial noise measurement and recording system using chart recorders to amass data, was placed into operation in November of 1985 [Ref. 3:p. 67]. The data on all ten channels was being collected and the chart recorder paper being changed every two weeks as designed. On January 26, 1986 a mild earthquake occurred in the general vicinity of the Hollister site. Less than 1 km away from the detection system a local winery had a large cask of wine fall from its stand as a result. Analysis of the data obtained from the chart recordings for the time frame surrounding the incident appears to support the observations of the amateur and citizen band radio operators. An increase in the general background noise floor prior to the quake occurred, as well as a sharp decrease in the level just prior to the quake. Figure 2.2 illustrates the radio frequency noise levels for the January 25 to 27, 1986 period on both the 38 MHz and 150 MHz frequencies.

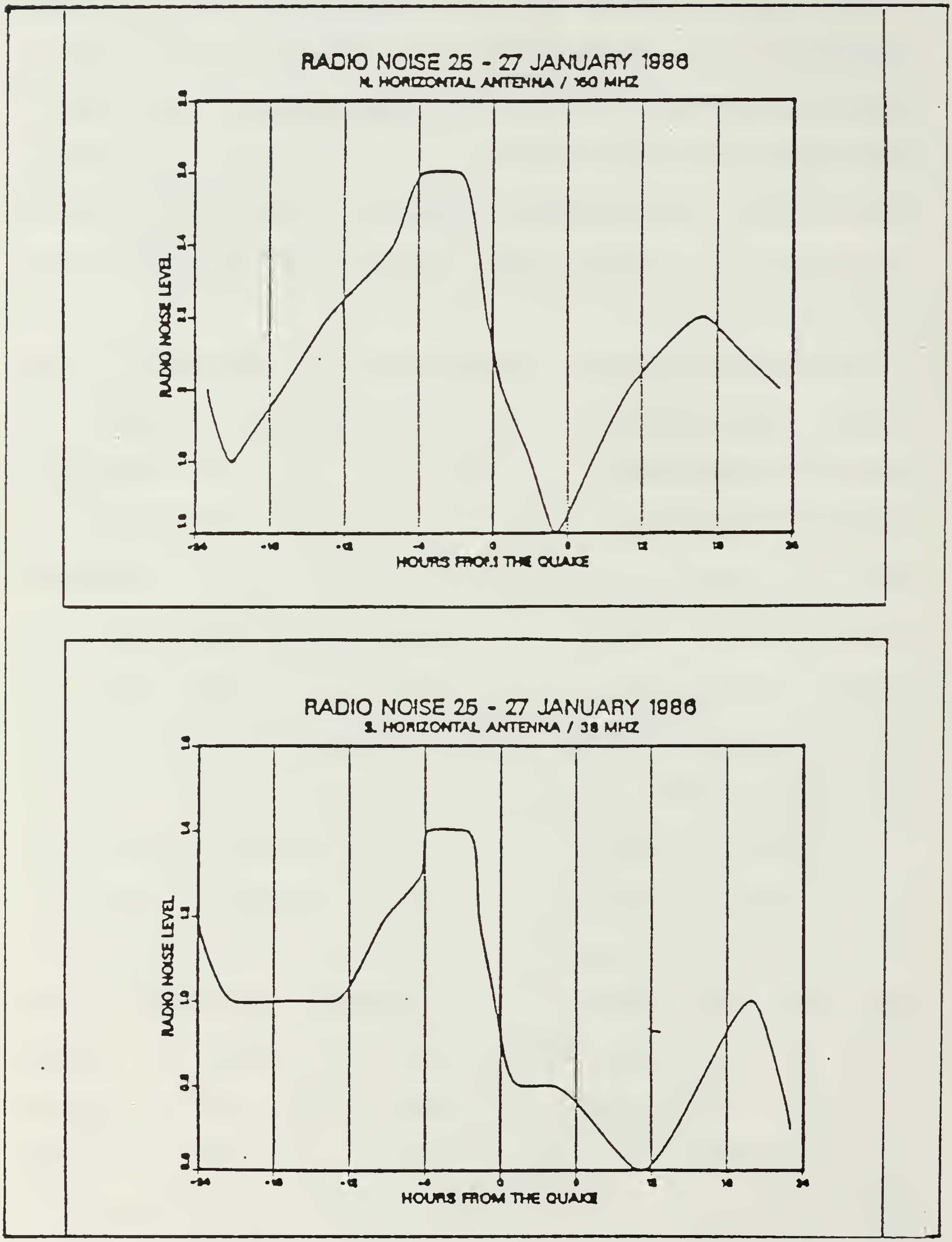


Figure 2.2 Collected Data for 25 to 27 January 1986

III. THE SATELLITE LINK

A. GENERAL BACKGROUND

To fulfill the requirement that the currently designed computer controlled VHF noise measurement and recording system be capable of having the collected data transmitted over a satellite link, the U.S. Geological Survey Office proposed the use of a commercial transmitter which utilizes the Geostationary Operational Environmental Satellite Data Collection System. Commercial UHF satellite transmitters are currently being used to provide a remote sensing capability for selected environmental sensors and are compatible with this system. [Ref. 11] and [Ref. 12] provide the background information for interfacing the computer controlled VHF noise measurement and recording system to the established data collection satellite link. The system becomes a remote sensing device, providing ready access to the data without traveling to the site to retrieve the data stored on the magnetic disk. Specifics of the actual hardware interfacing of the designed system to the satellite link are provided later in the thesis. To provide a workable understanding of the system so future users are familiar with its overall operation, a basic overview of the satellite link is presented [Ref. 11:pp. 2-17] and [Ref. 12:pp. 2-9].

There are currently two functioning Geostationary Operational Environmental Satellites (G.O.E.S.) that are part of a system of earth and space environmental sensors which provide an almost continuous observational information flow to the ground based user stations. The GOES system is operated and controlled by the National Environmental Satellite Data and Information Service (NESDIS). The organization was formerly called the National Earth Satellite Service (NESS). NESDIS is a suborganization of the National Oceanic and Atmospheric Administration (NOAA) which is controlled by the U.S. Department of Commerce. The GOES system itslf was a result of the combined efforts of NESDIS and the National Aeronautics and Space Administration (NASA) based on the experiments with the NASA advanced technology satellites.

The GOES system consists of several subsystems, one of which is the Data Collection System (DCS). The Data Collection System uses the GOES spacecraft for the relay of data from remotely located sites on, or nearly on the surface of the earth. Of course these remote sites must be in radio view of the satellite. There are many other uses for the GOES satellite, but the discussion of these is beyond the scope of this thesis.

There are two GOES satellites located in geosynchronous orbits over the equator at 75 degrees West and 135 degrees West longitudes. The radio view of the two spacecraft is from approximately 0 degrees westward to 165 degrees East longitude. There is a limitation of the coverage to approximately 77 degrees North and South latitudes. See Figure 3.1. In case of a failure of either the "East " or "West" satellites just mentioned, there is a third geostationary satellite in a geosynchronous orbit halfway between them at 107 degrees West longitude. This craft is also used to prevent data loss as a result of either satellite being temporarily out of commission as a result of an eclipse period.

B. THE GOES DATA COLLECTION SYSTEM

The GOES Data Collection System (DCS) is a satellite based system for the collection of a large variety of environmental data obtained from almost any point in the Western Hemisphere. It is a data relay network composed of literally thousands of individual data gathering devices known as Data Collection Platforms that each transmit the data they have acquired to one of the GOES satellites. The signal is then relayed from the satellite to the Command and Data Acquisition (CDA) Ground Station located in Wallops Station, Virginia.

The transponders carried onboard the GOES spacecrafts relay the UHF transmissions from the Data Collection Platforms (ranging rom 401.7 MHz up to 402.1 MHz) via S-band transmission to the ground receiving station. Conversely, S-band transmissions from the

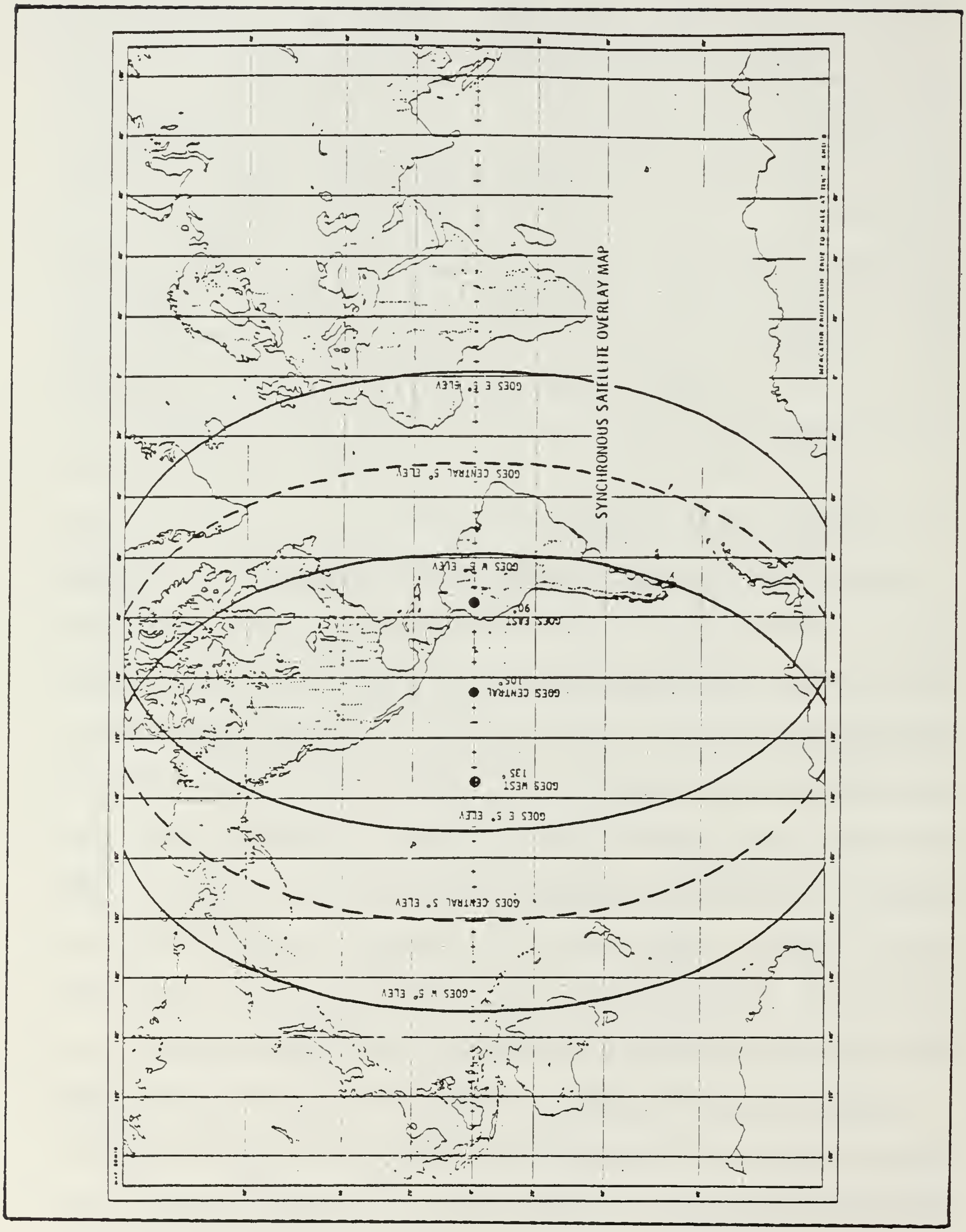


Figure 3.1 G.O.E.S. Satellite System Area of Coverage

NESDIS ground station can be relayed through the spacecraft transponder and converted into a UHF transmission for dissemination to properly equipped receivers in radio view of the satellite.

The satellite transponders are capable of supporting up to 233 reply channels. There are 200 channels reserved for use by regional and domestic channels ranging from 401.7 MHz up to 402.0 MHz, each with a 1.5 KHz channel separation. The other 33 channels are for international use in the 402.0 MHz to 402.1 MHz range. Each has a 3.0 KHz channel separation. The ground system is limited to supporting 80 channels and 5000 Data Collection Platforms.

There are four functional subsystems of the GOES Data Collection System. They are as follows:

- Deployed Data Collection Platform Radio Sets
- East and West Spacecraft Transponders
- Command and Data Acquisition Station
- Central Data and Dissemination Facility

A brief discussion of each of these is necessary for a basic understanding of how the GOES Data Collection System operates and subsequently how the designed VHF noise measurement and recording system can interface with the satellite link to achieve the remote sensing capability. Figure 3.2 shows a block diagram of the G.O.E.S. Data Collection System.

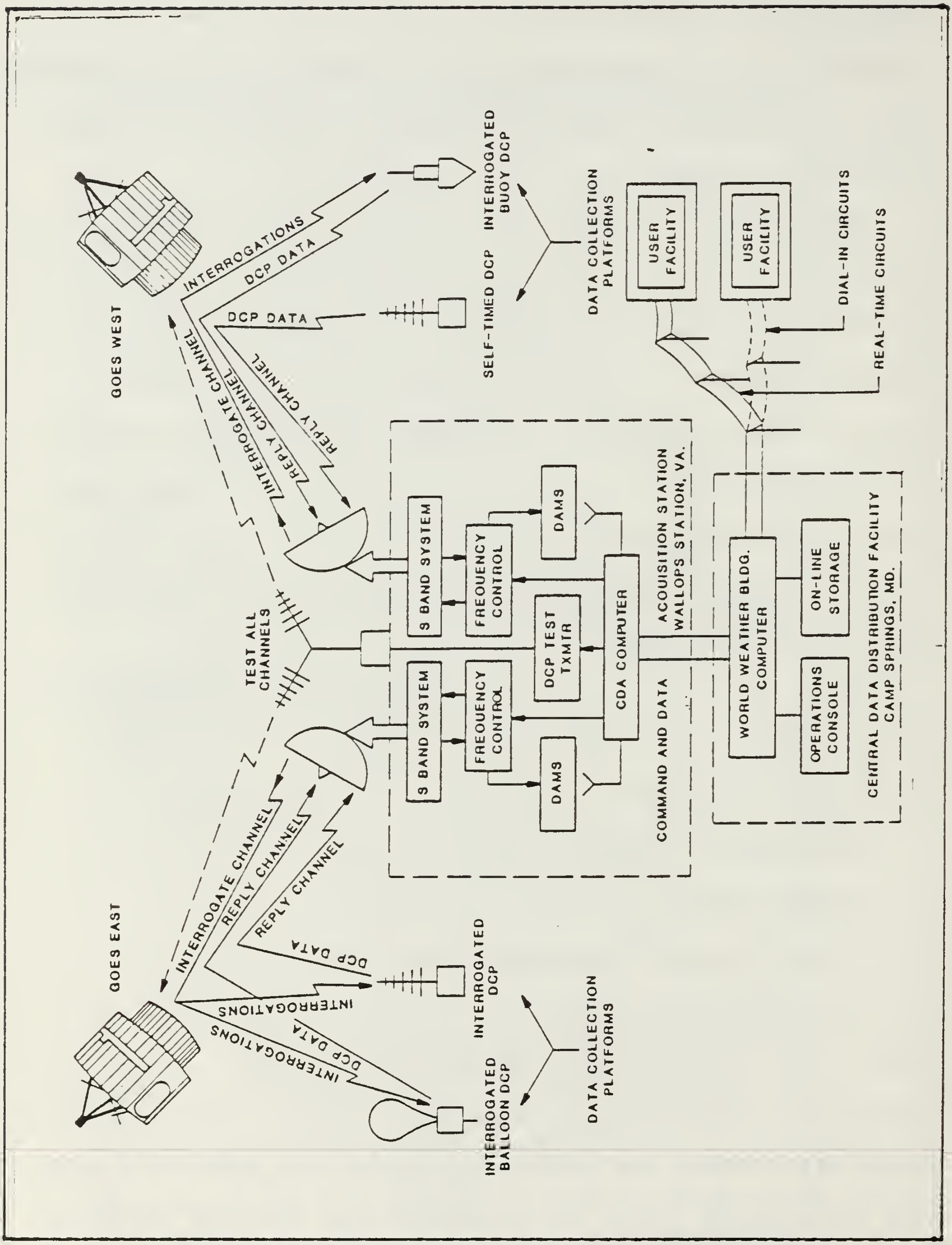


Figure 3.2 G.O.E.S. Data Collection System

1. Data Collection Platform Radio Sets

There are five different types of Data Collection Platform Radio Sets (DCPRS) which permit various modes of system operation. They are as follows:

- Self-Timed
- Self-Timed and Random Reporting
- Random Reporting
- Interrogated
- International Self-Timed

A description of each type follows.

a. Self-Timed

Self-Timed DCPRS contain only a transmitter and a timing source which is preprogrammed by the user to report during a specific hour at a specific minute and at a specific rate over a 24 hour period. The preprogrammed reporting time and rate of the DCPRS is not at all related to the cycle of the sensor attached to the platform. The sensor cycle refers to the time interval or frequency of when the environmental sensor attached directly to the DCPRS reads its specific data. The data is then placed into a memory buffer in the DCPRS for transmission at the preprogrammed time. For example, a DCPRS may have data transferred to it from an environmental sensor every five minutes, but this data would be stored temporarily and then transmitted through the GOES Data Collection System only once every three hours.

b. Self-Timed and Random Reporting

Self-Timed and Random Reporting DCPRS have the same characteristics as the previously mentioned type, however, it also has the ability to transmit over a secondary channel when environmental conditions require more frequent reporting than offered under self-timed operation. In this DCPRS the normal self-timed mode can be used under most circumstances, but if the need for more immediate data is required, the DCPRS can be automatically placed into the random reporting mode.

c. Random Reporting

The Random Reporting DCPRS contains a transmitter which will broadcast at a random time. This is controlled by environmental conditions being monitored by the sensor having reached a preassigned threshold. However, the Random Reporting DCPRS are also preassigned to report at least three times a day in order to assure that the DCPRS and the sensor are functioning properly.

d. Interrogated

Unlike the other types of DCPRS, the Interrogated DCPRS contain both a transmitter and a receiver. The onboard receiver is preset to either the East or West spacecraft DCPRS interrogation link frequency which enables it to detect its own unique identification or address when transmitted from the Command and Data Acquisition (CDA) Station at Wallops Station, Virginia. If a DCPRS recognizes its own special identification or callsign, it is programmed to transmit all of the data it has stored since the previous interrogation. The scheduling of the Interrogated DCPRS is very similar to the Self-Timed DCPRS, except that the schedule is stored at the Command and Data Acquisition Station instead of within the DCPRS themselves. The interrogation of the DCPRS may occur at intervals as small as 5 minutes or as large as once every 24 hours. In addition, some of the interrogated DCPRS have a secondary alert channel which will send an alert signal to the CDA telling it to interrogate because a preassigned threshold has been reached.

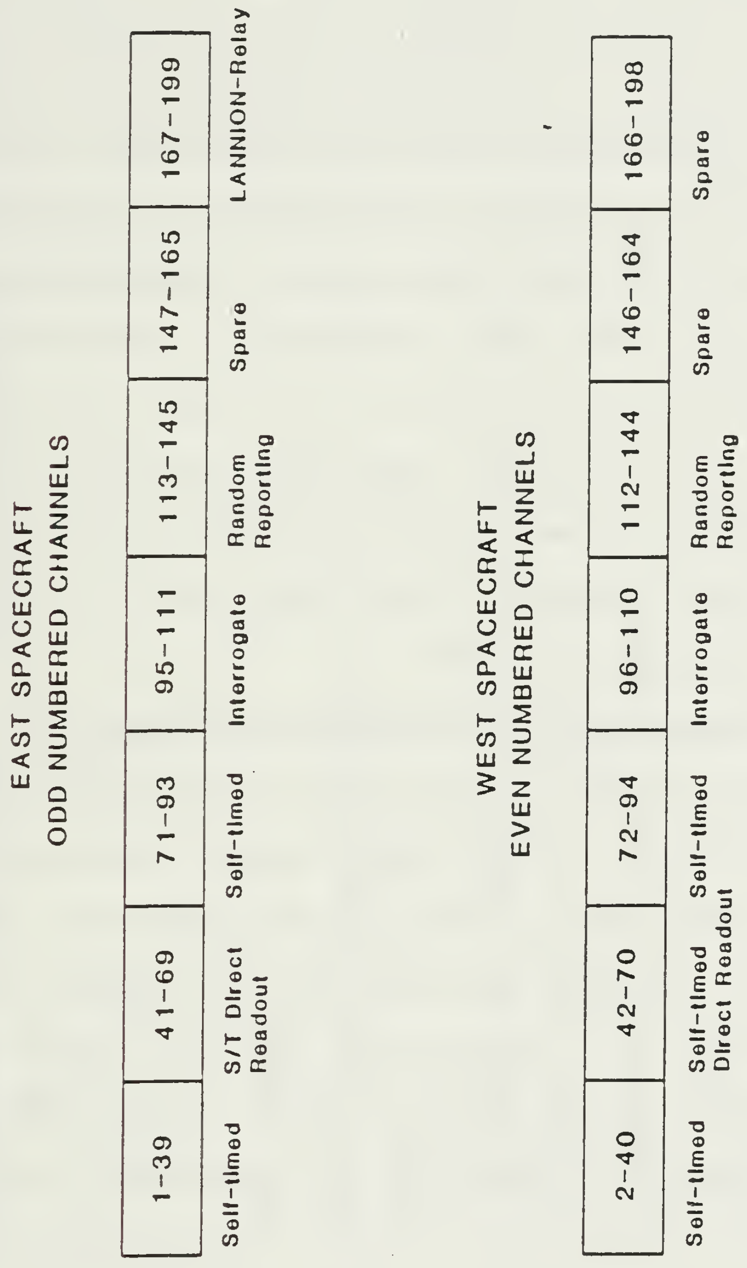
e. International Self-Timed

The International Self-Timed is identical to the domestic Self-Timed except for the range over which the UHF transmitters may transmit.

2. East and West Spacecraft Transponders

The next subsystem of the GOES Data Collection System to be discussed is the set of transponders aboard the East and West spacecraft. The GOES "East" spacecraft is located at 75 degrees West and the GOES "West" spacecraft at 135 degrees West. Each of the craft are capable of handling the 233 channels allocated for the system (200 domestic and 33 international). However, extra channel bandwidth is provided for all of the domestic channels by assigning the odd numbered channels to the East spacecraft transponder and the even channels to the West spacecraft transponder. As a result, a 3.0 KHz guard bandwidth is achieved between adjacent channels. A further organization of the channels is made by the assignment of certain blocks of channels on each spacecraft to specific types of DCPRS. See Figure 3.3 for a comparison of the odd/even channel assignments. The international channels are assigned to both the East and the West spacecraft at all times.

The Command and Data Acquisition Station sends out command and interrogate signals to the appropriate spacecraft transponder at an S-band frequency that is transformed into a UHF signal. Each spacecraft transponder sends out a different UHF frequency to the Data Collection Platform Radio Sets. The assigned frequency for the East is 468.8375 MHz and the assigned West frequency is 468.825 MHz. The response signals sent up from the Interrogated DCPRS and the self-transmitted signals from the Self-Timed and the Random Reporting DCPRS are sent up at UHF frequencies. The signals are then translated by the satellite transponders to S-band and then retransmitted to the Command and Data Acquisition Station.



EAST SPACECRAFT
ODD NUMBERED CHANNELS

1-39	41-69	71-93	95-111	113-145	147-165	167-199
Self-timed	S/T Direct Readout	Self-timed	Interrogate	Random Reporting	Spare	LANNION-Relay

WEST SPACECRAFT
EVEN NUMBERED CHANNELS

2-40	42-70	72-94	96-110	112-144	146-164	166-198
Self-timed	Self-timed Direct Readout	Self-timed	Interrogate	Random Reporting	Spare	Spare

Figure 3.3 East and West Spacecraft Channel Numbering

3. Command and Data Acquisition Station (CDA)

The messages are received from either one of the spacecraft via their S-band transmissions into the CDA. The received Data Collection Platform Radio Set messages are then routed to the Data Acquisition and Monitoring Subsystem (DAMS) units which will demodulate the data and perform signal quality measurements. A typical DCP message containing the DAMS quality information is shown in Figure 3.4. The data information is then transferred from the CDA to the Central Data and Dissemination Facility over high speed dedicated circuits for further dissemination. As mentioned previously, the CDA computer contains the schedule files for the Self-Timed and Interrogated types of DCPRS.

4. Central Data and Dissemination Facility

The Central Data and Dissemination Facility (CDDF) is located in the World Weather Building at Camp Springs, Maryland. There are two identicial computers there. One of them is on-line at all times, while the other is used for statistical analysis. The incoming messages from the Command and Data Acquisition Station are then routed to the users of the DCPRS via landline along with any pertinent error information detected during the processing of the message.

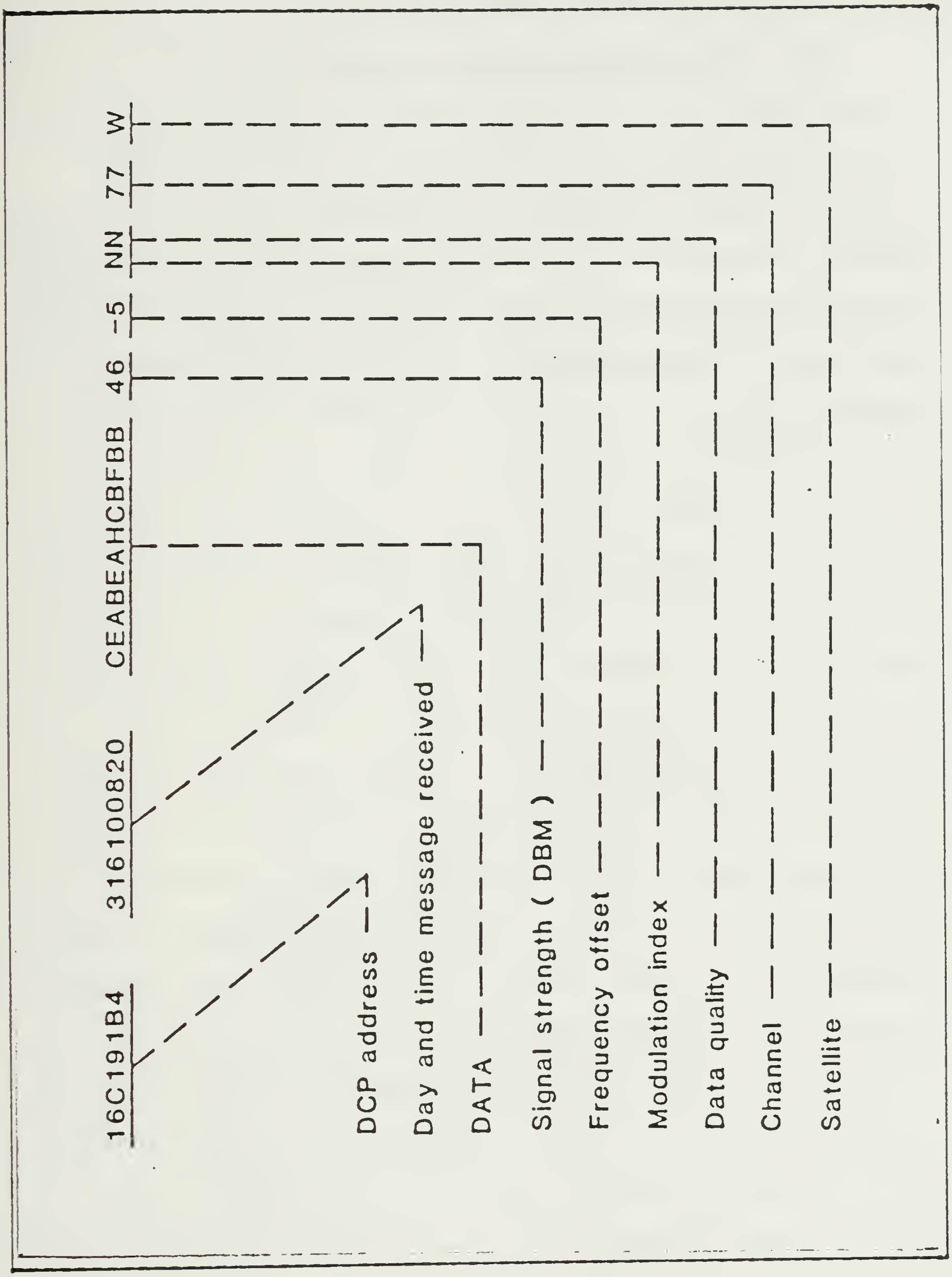


Figure 3.4 Typical Data Collection Platform Message

C. DIGITAL SATELLITE LINK INTERFACE

The designed computer controlled VHF noise measurement and recording system is capable of sending binary data out of an RS232 port in a serial format with a number of software programmable variations of the data bit stream. A detailed analysis of how the system can forward the acquired data to the buffer in a Data Collection Platform Radio Set will be presented later in this thesis.

IV. DESCRIPTION OF RESEARCH

A. DESIGN OVERVIEW

The design, construction and implementation of the computer controlled radio frequency (RF) noise measurement and recording system was accomplished by advancing the previous research into precursory electromagnetic activity associated with earthquakes [Ref. 3] and [Ref. 6]. The location of the installed monitoring system is three miles east of San Juan Batista, California and seven miles south of Hollister. This site is located within the Hollister Hills State Vehicular Recreation Area (upper ranch), directly south of the MX track. The site was chosen in previous research projects because it is historically an active location. In addition, the location is remote enough to be considered a rural area with respect to man-made radio noise. Figure 4.1 refers. The exact location is one thousand feet from the San Andreas fault at 121 degrees and 23.5 minutes West longitude and 36 degrees 45.5 minutes North latitude. Figures 4.2 and 4.3 provide a detailed means of locating the site.

The completion of the thesis involved the coordination of efforts in both hardware and software design to accomplish the established goals of obtaining

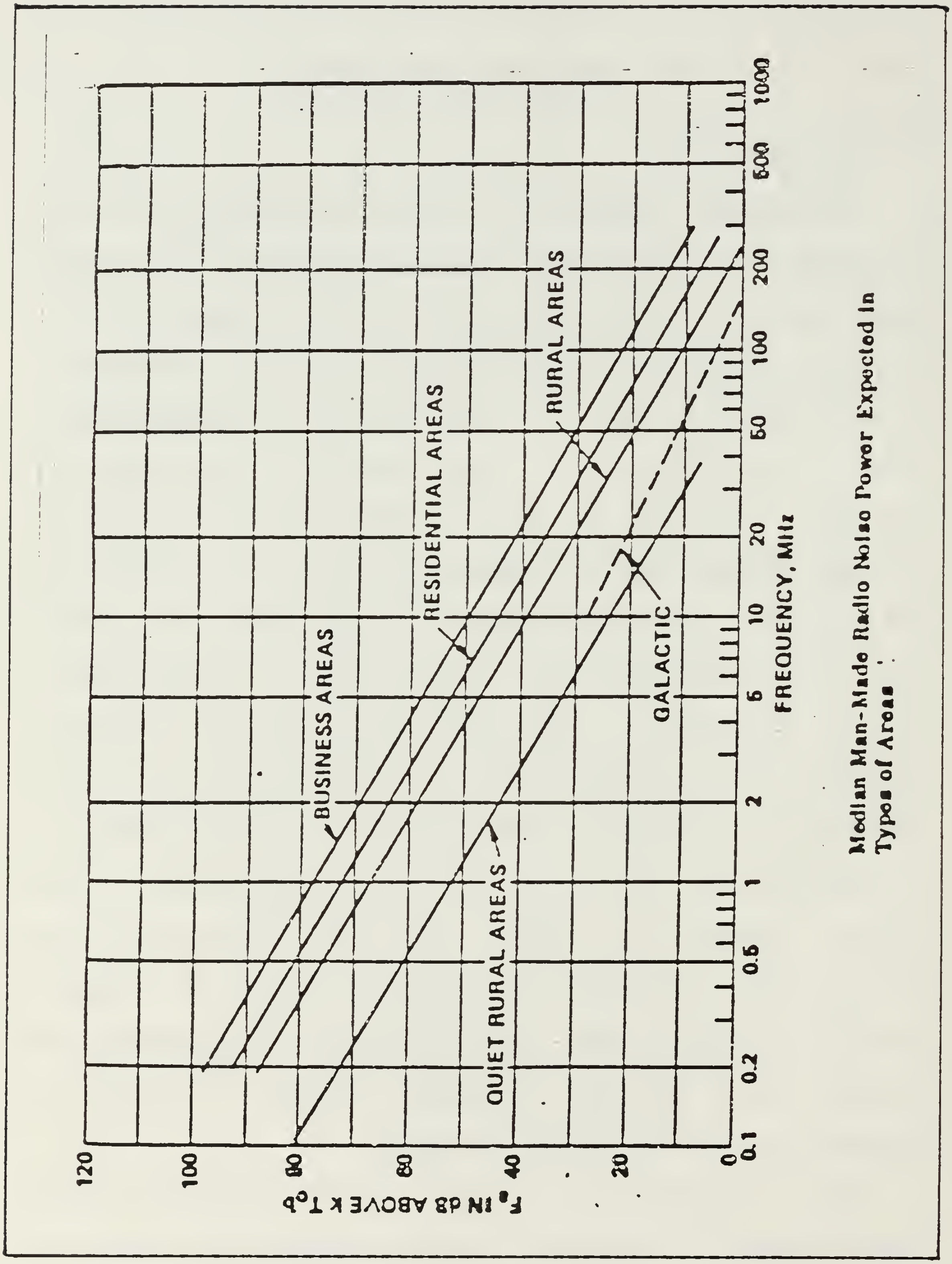


Figure 4.1 Median Man-Made Radio Noise Power Expectations

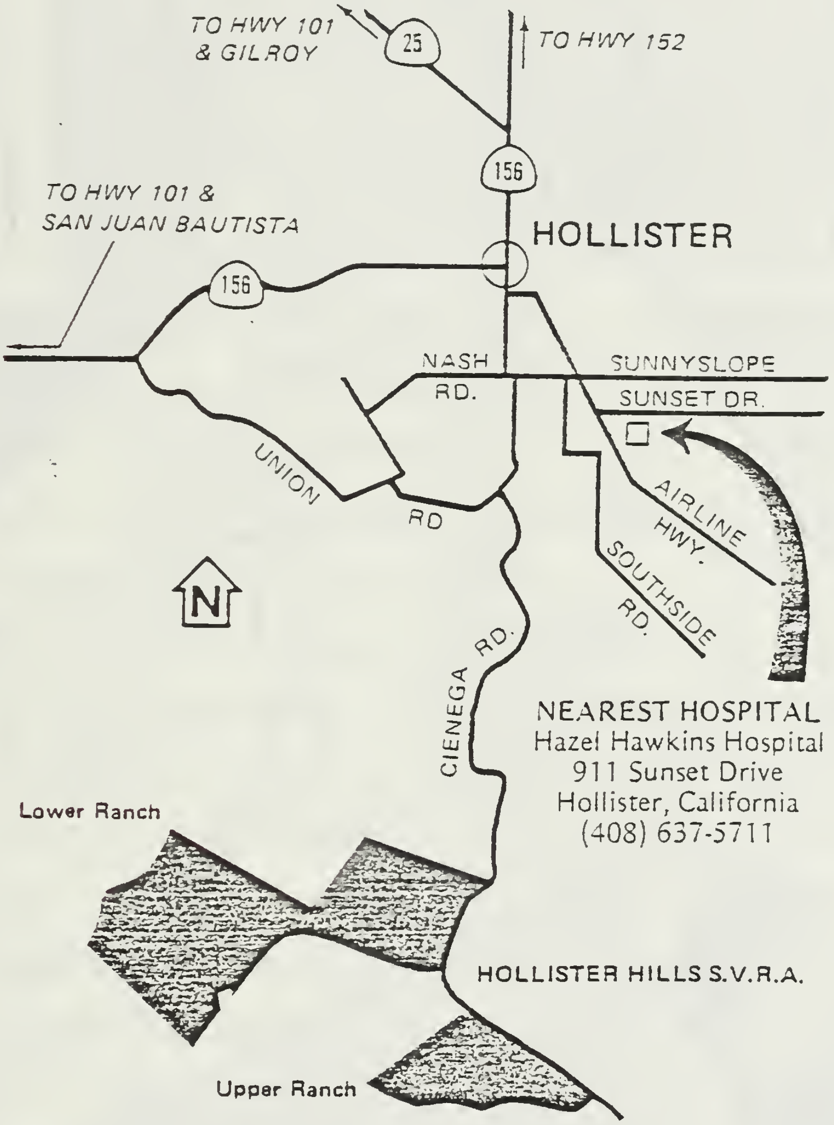


Figure 4.2 Site Location

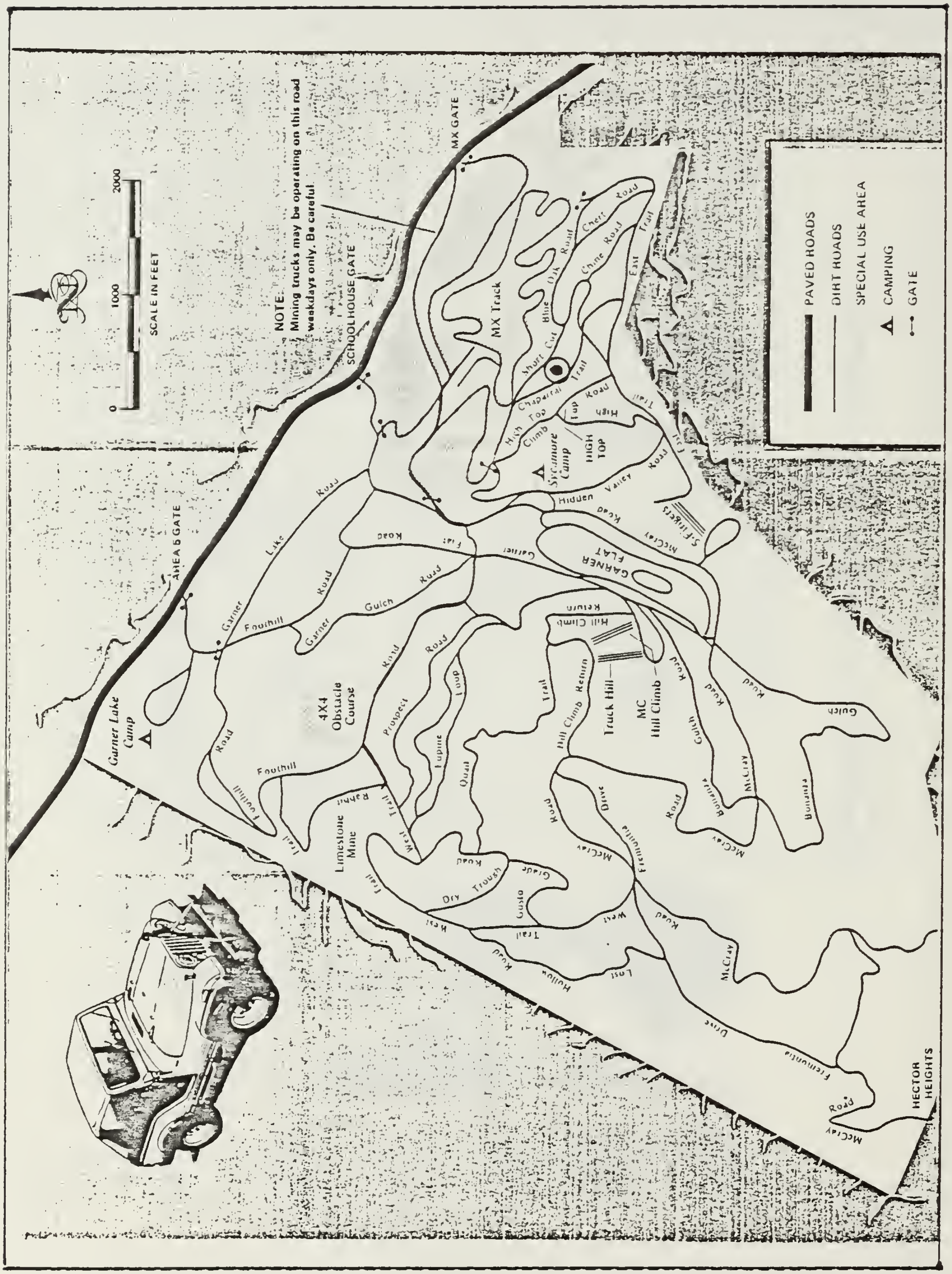


Figure 4.3 Site Location

a data recording and analysis system, as well as the digital satellite link. Figure 4.4 provides a block diagram of the hardware system and a flow chart of the software used on the Naval Postgraduate School IBM 3033 computer to provide graphical display of the data stored on 5.25 inch magnetic disks. The two frequencies being monitored (38.45 MHz and 150.75 MHz) have a bandwidth of 50 KHz. They have been established as receive only channels to allow the Naval Postgraduate School to investigate the short and long term variations of backround noise (noise floor). The Army Frequency Coordinator for the Western United States will continue these assignments on a yearly basis.

The antenna structure consists of two twenty foot towers and ten antennas. Each tower has five antennas mounted on it. Eight yagi antenna receive the horizontally and vertically polarized signals of the two frequency ranges. Omni antenna for each of the frequencies are vertically mounted. See Figure 4.5 for a list of the specific channel assignments. The signals received by each of the antenna are individually cabled to ten modular amplitude modulation (AM) receivers.

Once the receiver has processed a signal, a voltage level corresponding to the strength of this incoming signal is obtained from the "S" meter output. This output voltage level is sent to an interface amplifier

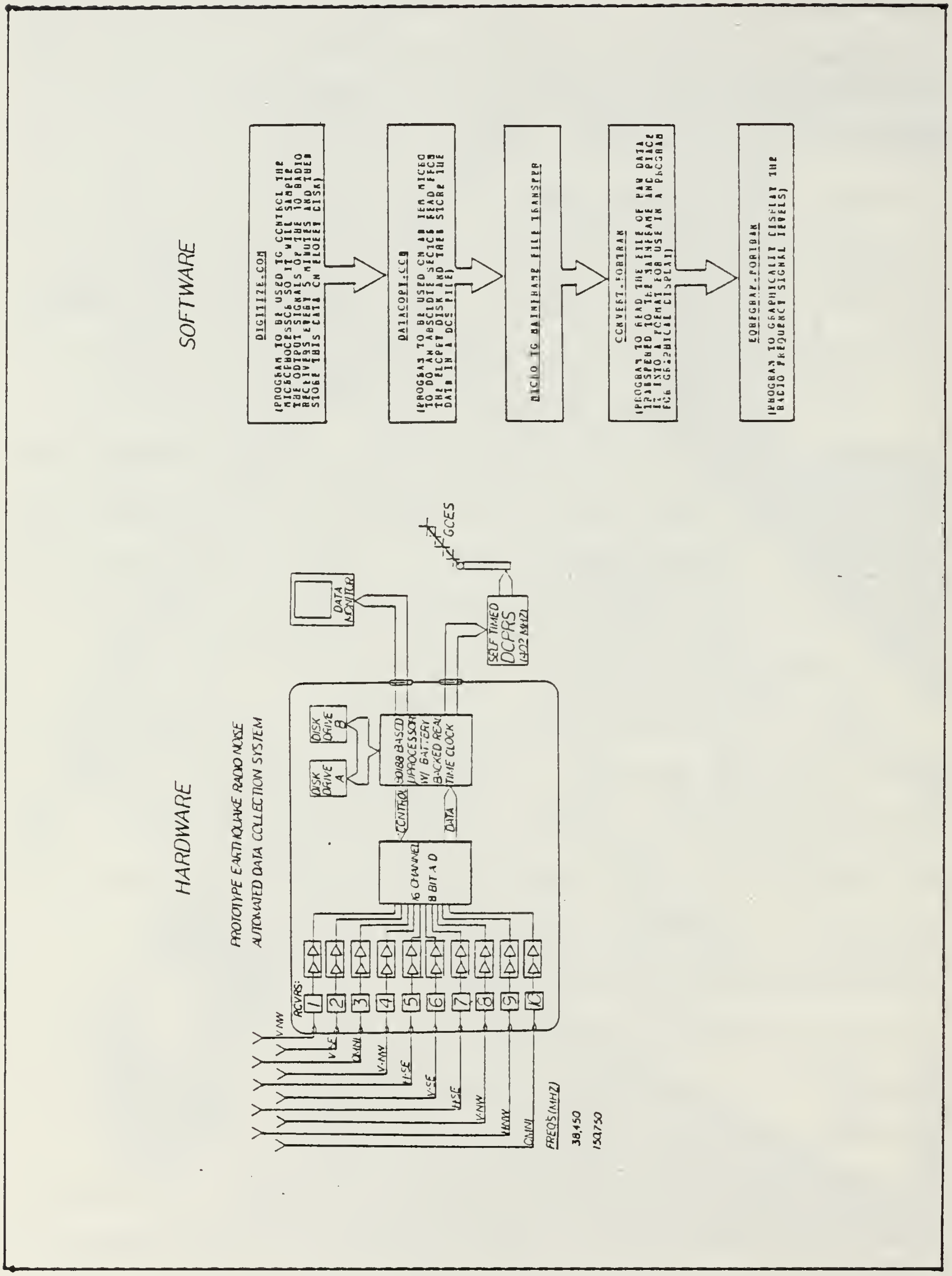

HARDWARE
PROTOTYPE EARTHQUAKE RADIO NOISE
AUTOMATED DATA COLLECTION SYSTEM
RCVRS:
1
2
3
4
5
6
7
8
9
10
V-NW
V-SE
OMNI
V-NW
H-SE
V-SE
H-SE
V-NW
H-NW
OMNI
FREQS (MHZ)
38,450
150,750
16 CHANNEL
8 BIT A D
CONTROL
DATA
80188 BASED
µPROCESSOR
W/ BATTERY
BACKED REAL
TIME CLOCK
DISK DRIVE A
DISK DRIVE B
DATA MONITOR
SELF TIMED
DCPRS
(402 MHZ)
GOES
SOFTWARE
DIGITIZE.COM
(PROGRAM TO BE USED TO CONTROL THE MICROPROCESSOR SO IT WILL SAMPLE THE OUTPUT SIGNALS OF THE 10 RADIO RECEIVERS EVERY 5 MINUTES AND THEN STORE THIS DATA ON FLOPPY DISK)
DATACOPY.COB
(PROGRAM TO BE USED ON AN IBM MICRO TO DO AN ABSOLUTE SECTOR READ FROM THE FLOPPY DISK AND THEN STORE THE DATA IN A DOS FILE)
MICRO TO MAINFRAME FILE TRANSFER
CONVERT.FORTRAN
(PROGRAM TO READ THE FILE OF RAW DATA TRANSFERRED TO THE MAINFRAME AND PLACE IT INTO A FORMAT FOR USE IN A PROGRAM FOR GRAPHICAL DISPLAY)
EQRFGRAF.FORTRAN
(PROGRAM TO GRAPHICALLY DISPLAY THE RADIO FREQUENCY SIGNAL LEVELS)

Figure 4.4 Design Overview Diagram

CHANNEL ASSIGNMENTS

CHANNEL	FREQUENCY (MHZ)	POLARIZATION	DIRECTION
1	150.75	VERTICAL	NORTHWEST
2	150.75	VERTICAL	SOUTHEAST
3	150.75	OMNI	----------
4	150.75	VERTICAL	NORTHWEST
5	150.75	HORIZONTAL	SOUTHEAST
6	38.45	VERTICAL	SOUTHEAST
7	38.45	HORIZONTAL	SOUTHEAST
8	38.45	VERTICAL	NORTHWEST
9	38.45	HORIZONTAL	NORTHWEST
10	38.45	OMNI	----------

Figure 4.5 Channel Assignments

where it is amplified to a range of zero to five volts, corresponding to the minimum and maximum received signals of interest, respectively. The zero to five volt range signal is then quantized by an 8-bit analog to digital converter. The data is stored in an ASCII format on magnetic disk. The data is also sent out RS232 ports to a buffer on a Self-Timed Data Collection Platform Radio Set (D.C.P.R.S.) for later transmission over a satellite link, as well as to a data monitor for visual display of the sampled signal level data. Control of this process is obtained from a program stored in an erasable programmable read only memory (EPROM) chip on the single board computer. Power for the system is obtained from either an AC or DC source.

Data analysis is accomplished by plotting the data stored on magnetic disk by using the IBM 3033 network at the Naval Postgraduate School. The data is stored in a very compact manner onto a formatted disk. However, the disk must be retrieved once a month and a new one inserted. At this point the series of software programs illustrated in Figure 4.4 are performed to process the data. The raw data is first rearranged into a PCDOS file format. The PCDOS file is then transferred to the main frame using an established microcomputer link. The data is arranged into a sequential format by the next program. In the final stage of the processing the graphical plot is obtained. The complete process for obtaining a graphical representation of thirty days of signal level information for ten separate channels has been reduced to hours, as opposed to days or even weeks of effort required prior to implementation of this system. The collected data is easily and rapidly correlated to any additional earthquake related data provided by the Geological Survey Office in Menlo Park, California.

B. SYSTEM HARDWARE DESIGN AND OPERATION

The block diagram of the hardware components of the computer controlled RF noise measurement and recording system is presented again in greater detail in Figure 4.6. A close analysis of each of the individual subsystems is presented.

1. Receivers

Each one of the Hamtronics VHF converter modules are designed to amplify and convert a specific frequency to the HF range. Schematic diagrams of the 38.45 MHz and the 150.75 MHz converters are shown in Figure 4.7 and Figure 4.8, respectively. Each one of the converters have 10.7 MHz intermediate frequency (IF) transformers for the mixer output circuits. The mixer output circuits themselves consist of a slug tuned coil, capacitive voltage dividers and an RCA jack to provide a 50 ohm output.

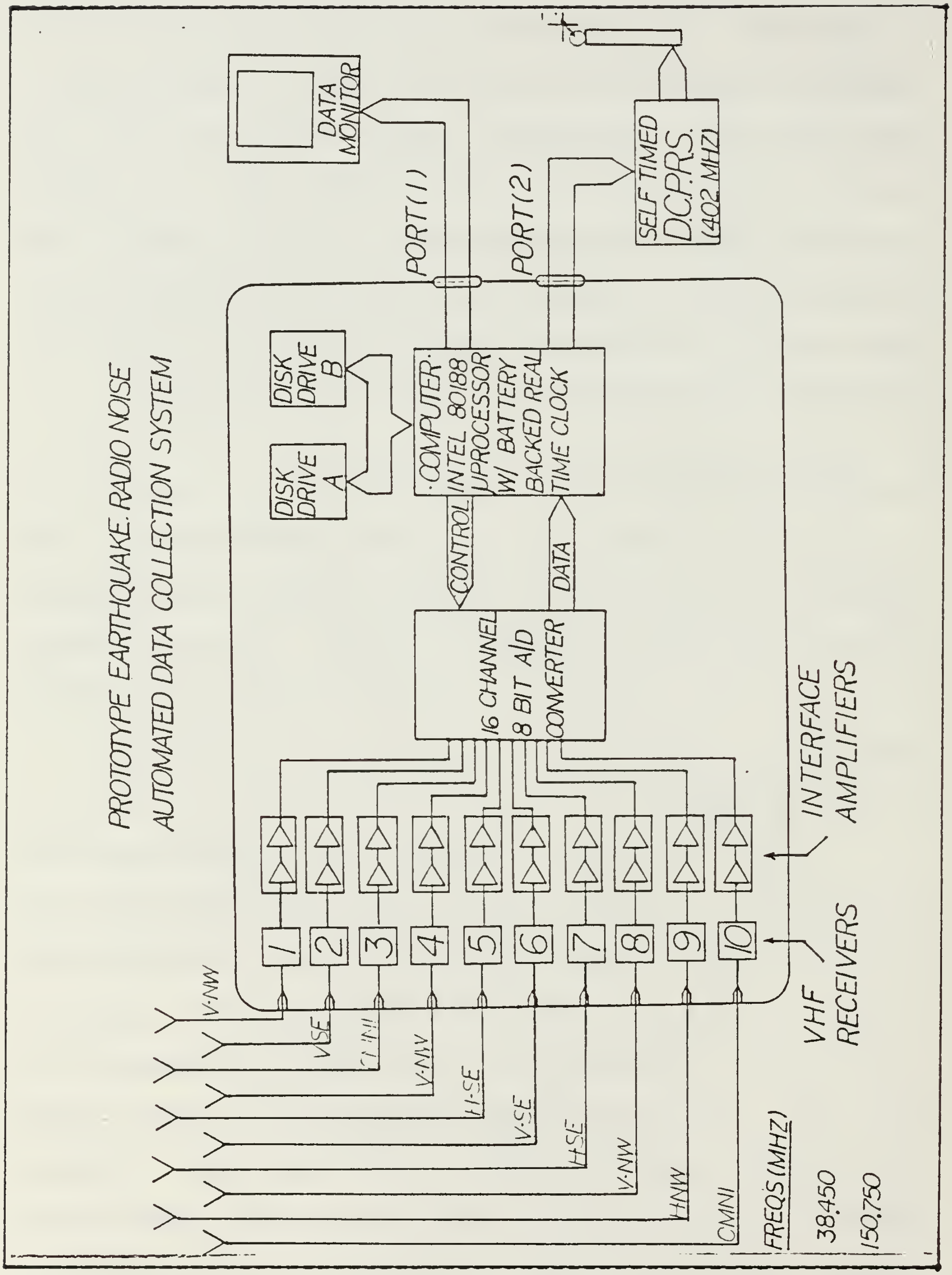

PROTOTYPE EARTHQUAKE RADIO NOISE
AUTOMATED DATA COLLECTION SYSTEM
DATA MONITOR
PORT (1)
PORT (2)
SELF TIMED D.C.P.R.S. (402 MHZ)
DISK DRIVE A
DISK DRIVE B
COMPUTER INTEL 80188 μPROCESSOR W/ BATTERY BACKED REAL TIME CLOCK
CONTROL
DATA
16 CHANNEL 8 BIT A/D CONVERTER
INTERFACE AMPLIFIERS
VHF RECEIVERS
1
2
3
4
5
6
7
8
9
10
V-NW
V-SE
OMNI
V-NW
H-SE
V-SE
H-SE
V-NW
H-NW
OMNI
FREQ'S (MHZ)
38.450
150.750

Figure 4.6 System Hardware Block Diagram

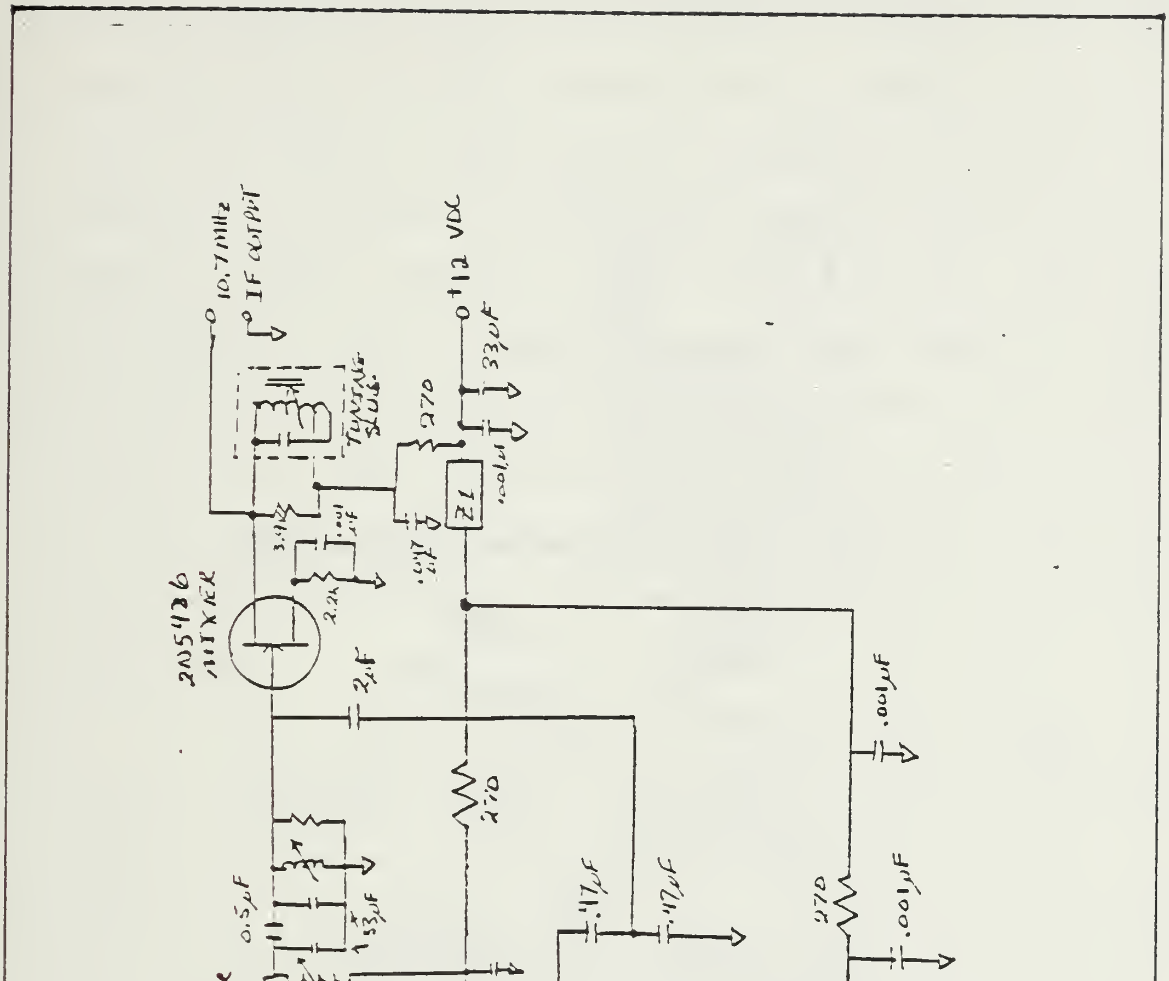


Figure 4.7 38.45 MHz VHF Converter

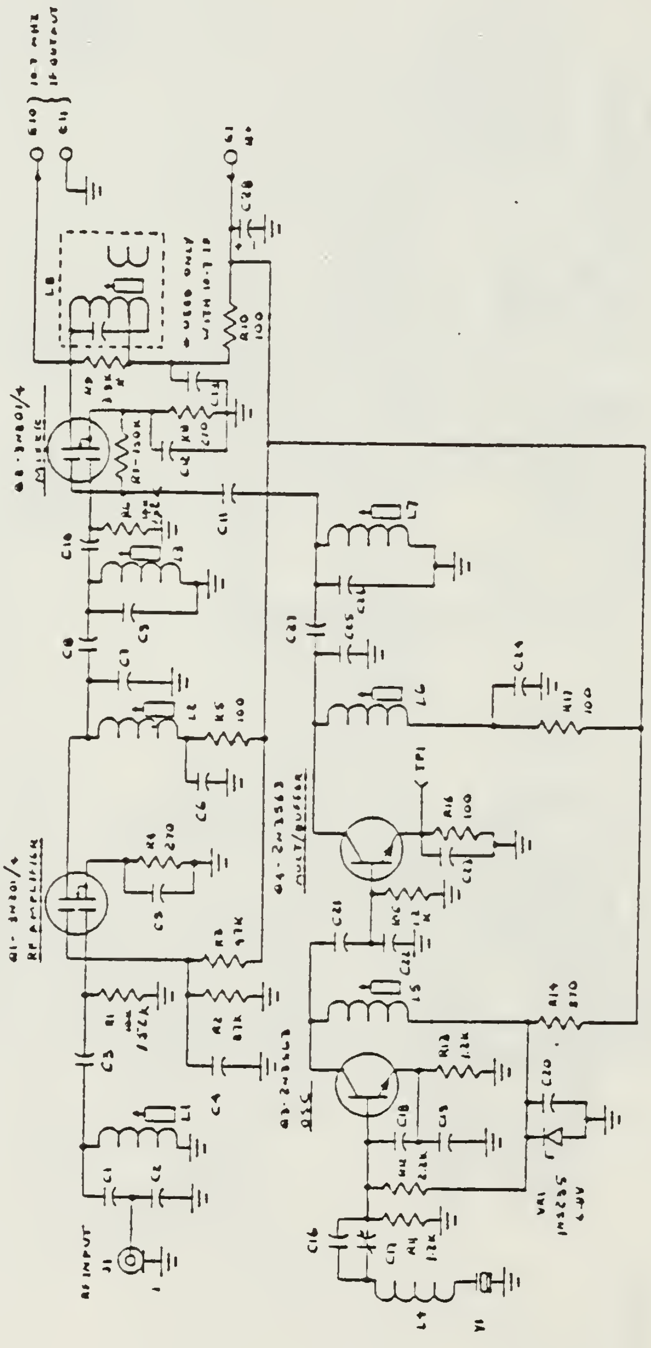


Figure 4.8 150.75 MHz VHF Converter

The 10.7 MHz IF signal is sent from the converter module to the IF/Audio module shown in Figure 4.9. The IF/Audio assembly is a highly sensitive and selective IF ampliier, AM detector, audio amplifier and squelch system which is used in conjunction with the converter to create a VHF communications receiver. The HF signal is then mixed with the 10.245 MHz oscillator frequency and then down-shifted to 455 KHz. This signal is then amplified and detected. The "S" meter output to the interface amplifier is obtained from an integral log detector.

The selectivity of this unit (plus or minus 10 KHz at -6dB and plus or minus 25 KHz at -60 dB) will permit its use as a noise floor measurement system. An optimally coupled three stage IF filter provides the selectivity against adjacent channel interference. The unit has automatic gain control (AGC) for both IF and RF, with the RF AGC being delayed for best response. Each receiver is installed in its own individual aluminum casing to prevent the detrimental effects of electromagnetic inteference (EMI).

2. Interface Amplifiers

The "S" meter output from the integral log detector in the receiver is sent directly to the interface amplifier assembly shown in Figure 4.10. Previously the "S" meter output and a time pulse from a

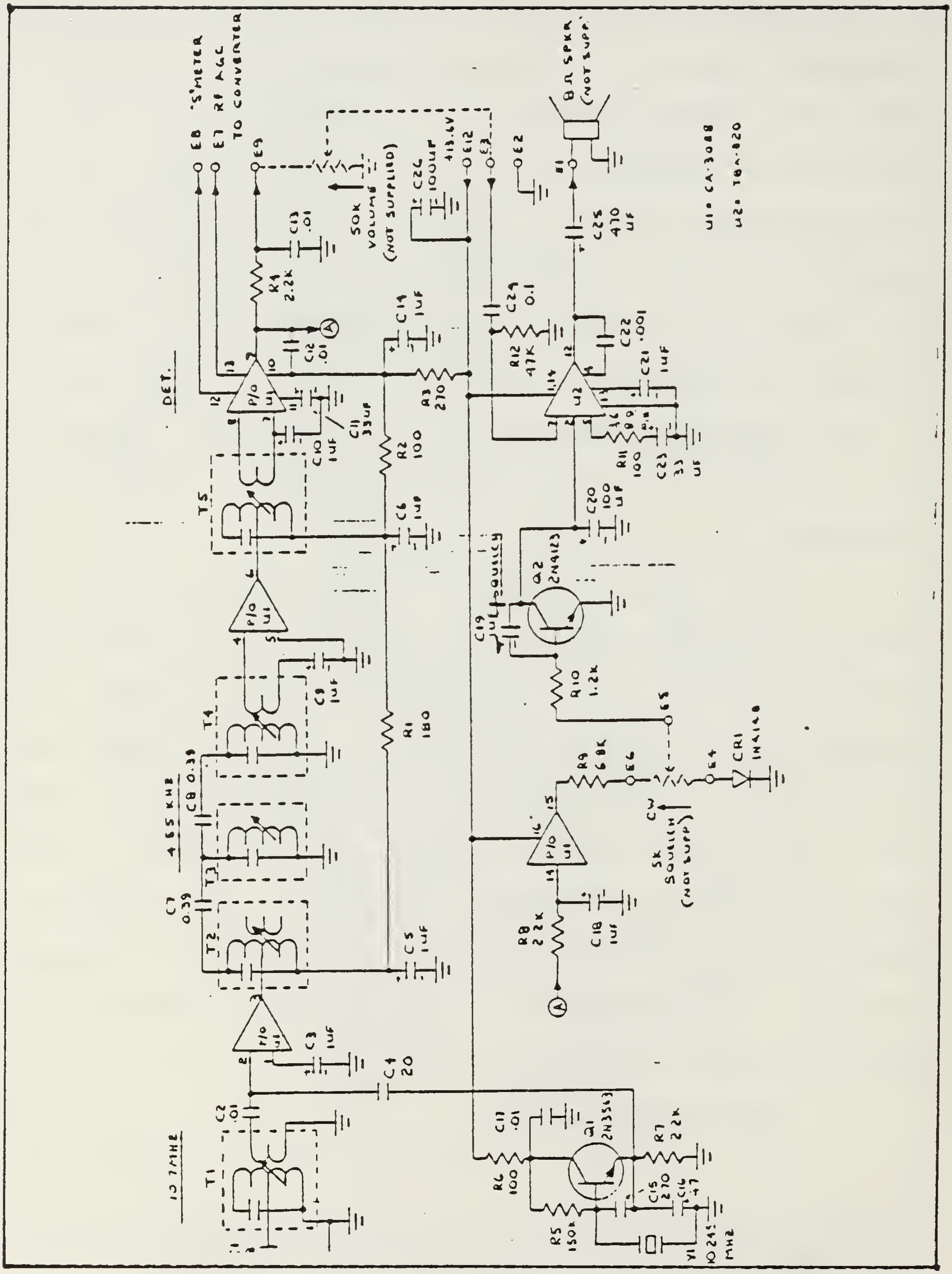


Figure 4.9 IF/Audio Assembly

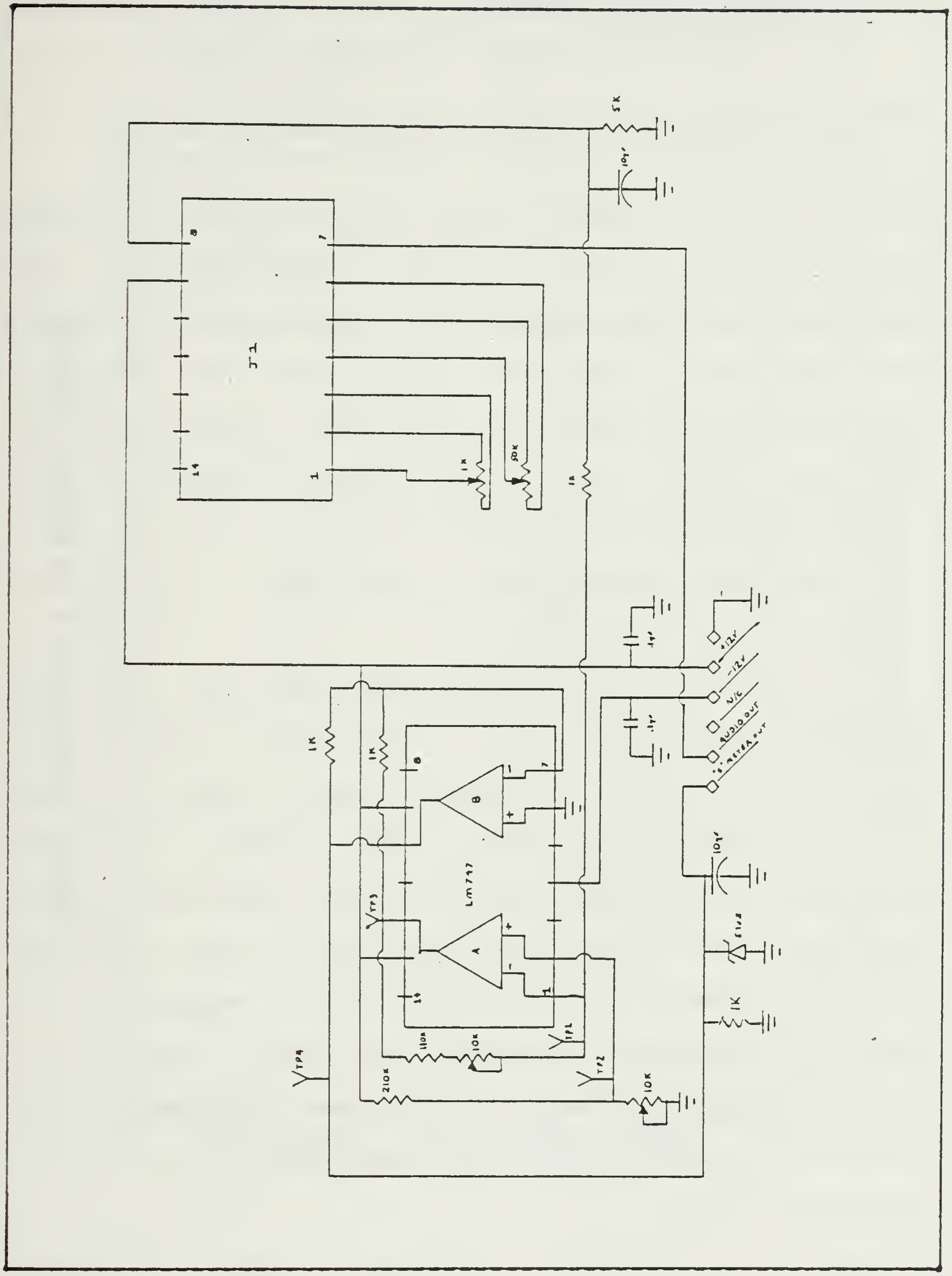


Figure 4.10 Interface Amplifier

timer assembly were integrated into one signal [Ref. 3: p. 58]. Observation of the data found the design to be sensitive to temperature and subject to nonlinear variations in output levels. In the current system a great deal of simplification has resulted by utilizing the computer as the timing and control device. The interface amplifier uses LM747 series general purpose dual operational amplifiers. As a result, no frequency compensation is required and there is an inherent balanced offset null. The "S" meter output of the receiver is amplified by the first stage, then inverted to a positive voltage using a unity gain in the second stage.

Previous data monitoring indicates that the received input signals fell in the range of zero to ten microvolts. Amplification of these signals to the millivolt range is available at the "S" meter output of the receivers. The signal is then amplified to the required range of zero to five volts by the interface amplifier assembly, correspondiong to the required input range of the analog to digital converter. Figure 4.11 provides a graphical plot of the input RF signal to the receiver versus the corresponding analog to digital converter input.

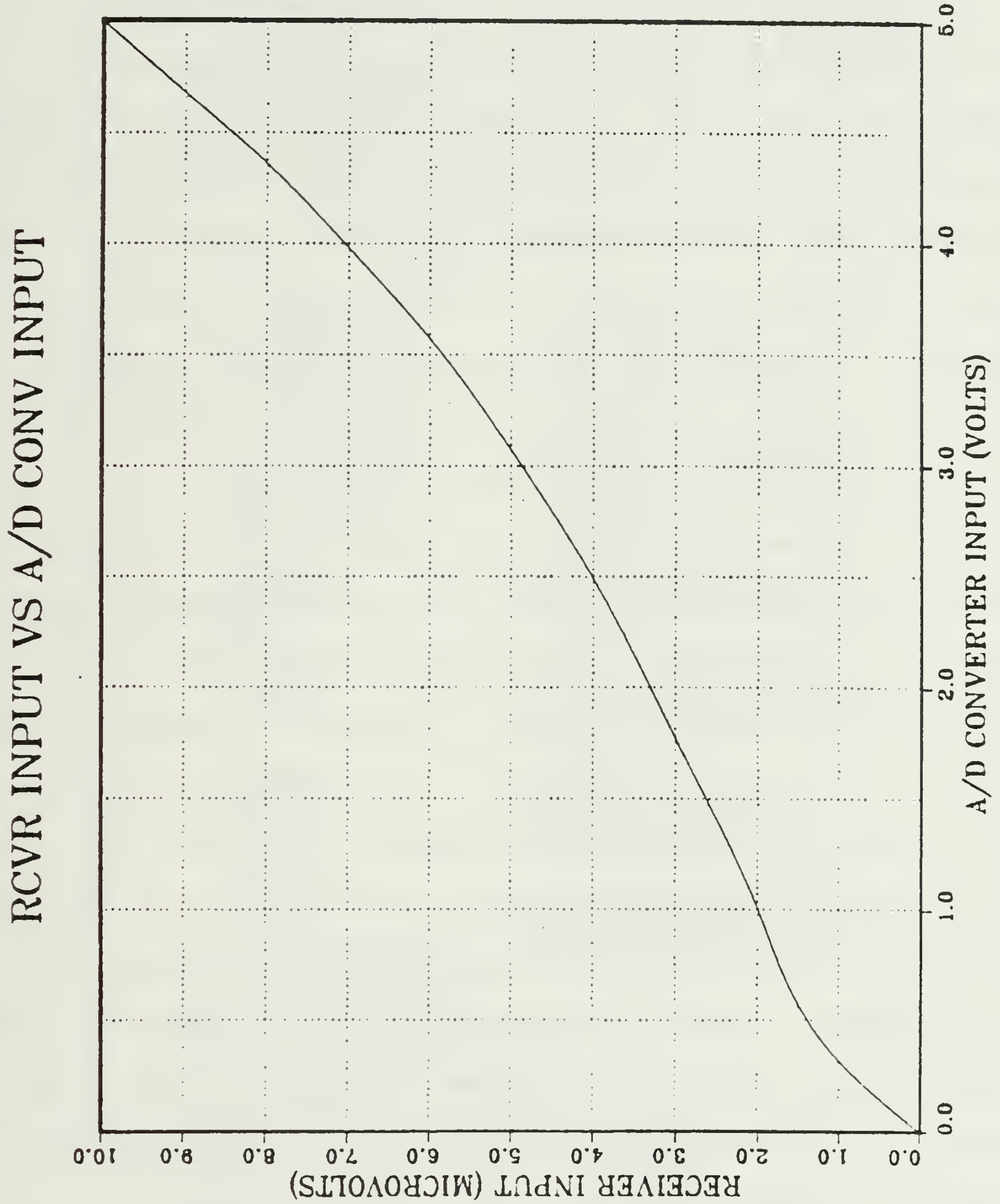


Figure 4.11 Graph of Receiver Input vs A/D Converter Input

3. Analog To Digital Converter

Quantizing of the zero to five volt signal level from the interface amplifier assembly is accomplished by an 8-bit analog to digital converter. The 16 channel 8-bit A/D converter with the associated address decoder and multiplexing circuitry are located on the Vesta OEM188 multifunction board shown in Figure 4.12. The board has been jumpered to allow single-ended analog inputs. Port 5 (P5) on the multifunction board will allow for up to 16 channels of single-ended analog input. (P5) is set up as shown in Table I.

The multifunction card has a bus interface to allow for direct connection to the microprocessor board. The bus interface has a wait-state generator to induce a 1.2 microsecond hold state to stabilize the bus during input and output procedures. The wait-state generator will slow down the microprocessor to allow for the operation of slow input/output devices such as the A/D converter. The bus is configured as a 60 conductor, dual row header that is designated Port 1 (P1) on the multifunction card. The header is connected via ribbon cable to the expansion bus connector on the single board computer itself.

4. Computer

The Vesta OEM188 single board computer using an Intel 80188 microprocessor with a clockspeed of 8 MHz

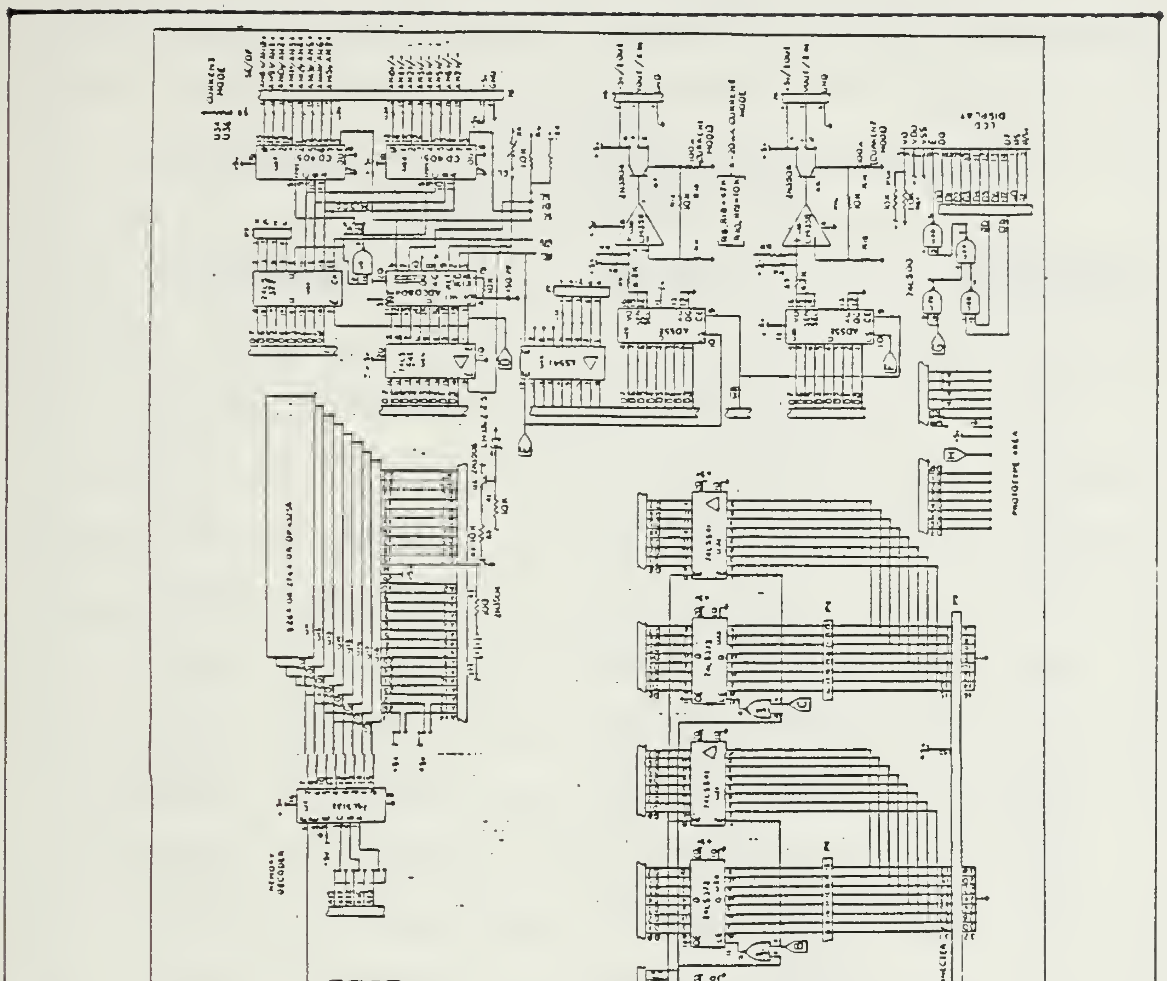


Figure 4.12 Schematic Diagram of Multifunction Board

TABLE I

MULTIFUNCTION CARD PORT 5 (P5) PIN ASSIGNMENT (A/D CONVERTER INPUTS)

PIN NUMBER	FUNCTION	ASSIGNMENT
22	Analog (+) 0	Channel 1 Input
24	Analog (+) 1	Channel 2 Input
26	Analog (+) 2	Channel 3 Input
16	Analog (+) 3	Channel 4 Input
23	Analog (+) 4	Channel 5 Input
18	Analog (+) 5	Channel 6 Input
25	Analog (+) 6	Channel 7 Input
20	Analog (+) 7	Channel 8 Input
9	Analog (+) 8	Channel 9 Input
11	Analog (+) 9	Channel 10 Input
13	Analog (+) 10	Unassigned
19	Analog (+) 11	Unassigned
15	Analog (+) 12	Unassigned
21	Analog (+) 13	Unassigned
17	Analog (+) 14	Unassigned
7	Analog (+) 15	Unassigned
8	Ground	Ground
10	+ 5 DC	+ 5 DC

provides a maximum level of control with minimal size requirements. The control program for the microprocessor has been stored on an EPROM, allowing the disk drives attached to the computer to be used solely for data storage. Both the operating system basic input/output system (BIOS) and higher level language compiler (BASIC) are also stored in ROM directly on the board. The computer has a battery-backed real time clock (National Semiconductor MM58274) mounted on it, as well as a WD1770 disk drive controller which will support up to four 5.25 inch disk drives. In addition, an EPROM programmer is located in socket U31 on the board to allow for direct storage of programs written on the computer in BASIC. A schematic of the computer is provided in Figure 4.13.

The terminal connector located at Port 3 (P3) is designed to drive a high speed full duplex CRT terminal. This is the primary means of operator communications with the computer. The three pins on the P3 connection and their corresponding functions are described in Table II. Communications take place over an RS-232 line at a rate selected by the configuration switch located on the single board computer itself. The function of this switch is twofold. The switch provides the system with information concerning the extent of low memory. The switch also determines the baud rate at which the CRT serial channel will communicate. Table III provides the

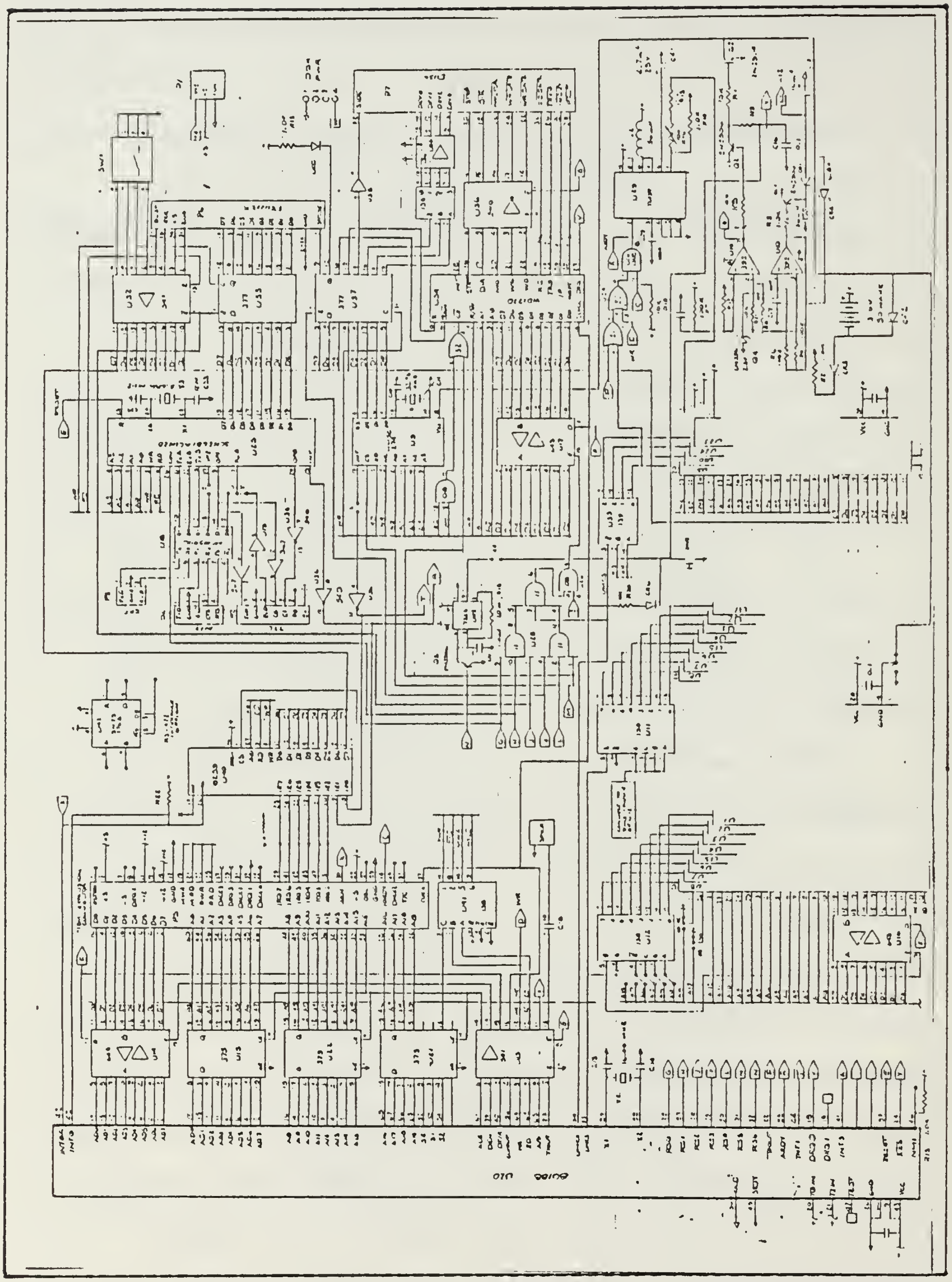


Figure 4.13 Schematic Diagram of OEM188 Computer

TABLE II

OEM188 PORT 3 (P3) PIN ASSIGNMENTS (TERMINAL CONNECTOR)

PIN NUMBER	FUNCTION
1	TXD, transmitted data from computer
2	GND, signal common
3	RXD, received data from terminal

TABLE III

OEM188 CONFIGURATION SWITCH SETTINGS

SWITCH SETTINGS	FUNCTION
0 X X X	< 64K Onboard low frequency
1 X X X	> 128K Onboard low memory
X 0 0 0	150 BAUD
X 0 0 1	300 BAUD
X 0 1 0	600 BAUD
X 0 1 1	1200 BAUD
X 1 0 0	2400 BAUD
X 1 0 1	4800 BAUD
X 1 1 0	9600 BAUD
X 1 1 1	19200 BAUD

correct settings for this switch. Switch positions are shown from left to right corresponding to pin numbers 1 to 4 (0 = closed, 1 = open). The current system incorporates only 16k of onboard low memory. The present configuration switch setting is 0-1-1-0 to accommodate terminal interfacing at a 9600 baud rate.

The power connector located at port 1 (P1) supplies the system with +5 VDC and +12 VDC. Pin 1 of P1 is connected to +5 VDC and pin 3 connected to ground. The +12 VDC connection is not required. As stated previously, up to four 5.25 inch floppy disk drives may be used. In the present arrangement, Port 7 (P7) has been connected to two disk drives via 34 conductor ribbon cable in a daisy chain. Power is supplied to the disk drives separately from the system's power supply.

Auxiliary RS-232 serial port 4 (P4) on the computer board is used to transmit the collected data to the Data Collection Platform Radio Set buffer for transmission over the satellite link at a later time. The information is sent out this port in a software programmable format. Table IV describes the pin assignments and their functions.

5. Disk Drives

Two Teac model FD-55B half-height double-sided double-density disk drives are installed in the system. The data disk is installed in the "A" drive to receive

TABLE IV

AUXILIARY RS-232 SERIAL PORT 4 (P4) PIN ASSIGNMENTS

PIN NUMBER	FUNCTION
1	TXD, transmitted data from computer
2	GND, signal common
3	RXD, received data
4	RTS, ready to send
5	CTS, clear to send

the digitized signal levels of all ten channels at each sampling interval. The "B" drive was used in the initial design of the computer control program and may be alternated with the current "A" drive for data storage. Both drives have been sealed in a dust, insect and vermin proof plexiglass container to prevent any possible damage to moving parts, the writing heads, or the data disk themselves.

Each drive has a power requirement of + 12 VDC at 0.9 amp max and + 5 VDC at 0.6 amp max. Typical power consumption while in operation is 3.9 watts and while idle 2.6 watts. The units are extremely reliable, with an operating temperature range of 4 degrees to 46 degrees centigrade and a relative humidity operating range of 20% to 80% (noncondensing).

6. Power Supply System

The system has been designed to operate using either 60 Hz, 115 volt AC power, or 12 volt DC power. Figure 4.14 shows the block diagram of the power supply system. When AC power is available, the system is designed to supply both plus and minus 12 volts DC and plus five volts DC. The battery chargers will maintain a constant charge on the 12 volt DC batteries until AC power is lost. At that time, the batteries instantaneously begin to provide the system with the

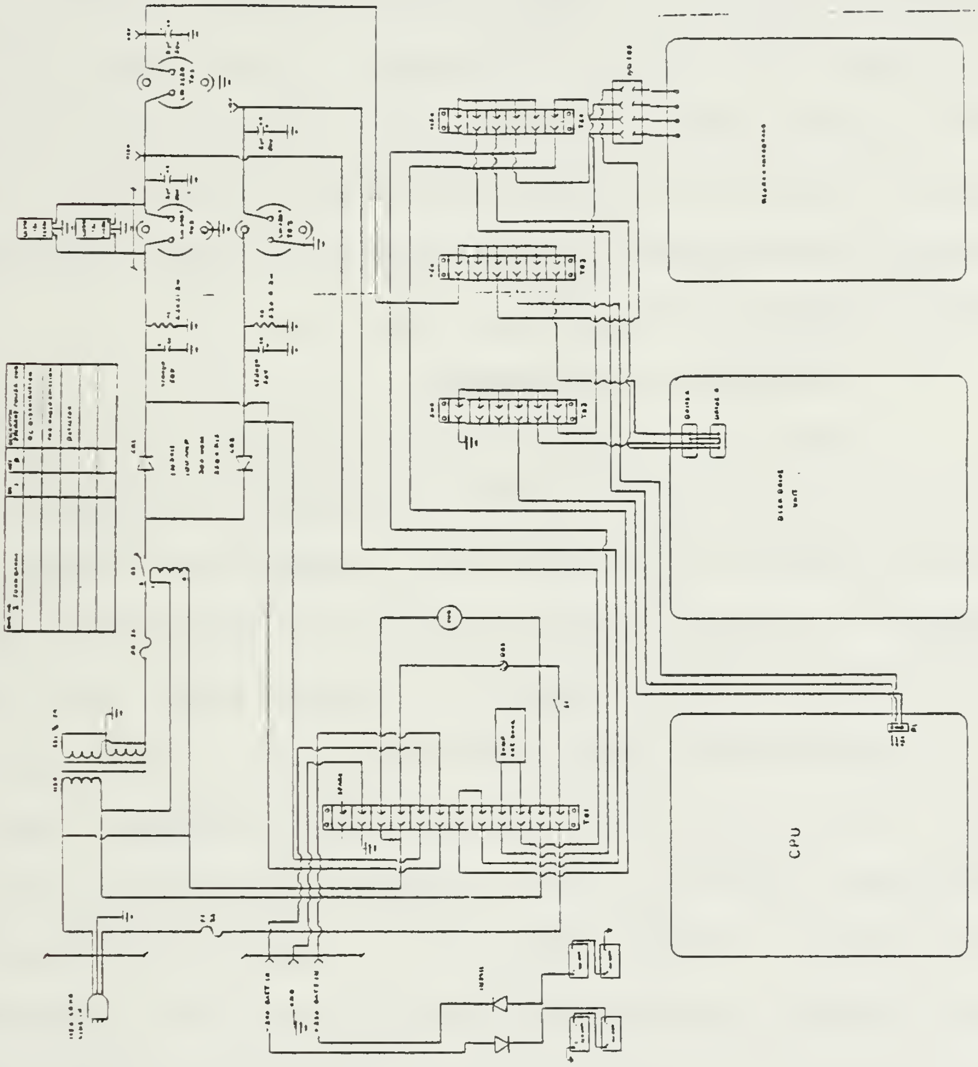


Figure 4.14 Power Supply System

required voltages. The batteries will maintain the system in full operation for approximately 48 hours. Even if the system were forced to operate without AC power for a period of time sufficient enough to drain the power batteries, the small nickel-cadmium battery on the computer board will provide power to the real time clock for up to a week. Although data storage capability will be lost during this time, the automatic reset of the computer will reactivate the control program immediately once AC power is restored.

7. Interface Connections

Two 25 pin male D-type connectors are installed on the front of the system enclosure to provide serial data output to the external peripherals. Output Port number 1 is wired to the terminal connector Port 3 (P3) of the computer. The pin connections and their corresponding functions are available in Table II. The baud rate at which the communication of data is sent out of output port 1 is set by the configuration switch on the computer. Table III provides the available options and correct settings for the switch. The switch is presently set to 0-1-1-0 to accommodate full duplex terminal interactions at a 9600 baud rate.

Data output port number 2 is connected to auxiliary RS-232 port 4 (P4) on the computer. At the time of each sampling interval the signal level data is sent out of this port in a serial format to the Data Collection Platform Radio Set buffer. The data is stored in the buffer until it is transmitted over the 402 MHz satellite channel at the predetermined interval. Table IV describes the pin assignments and their functions. The software design section describes in detail the options available in formatting the data output. The data is presently being sent out at a rate of 110 baud from output Port 2 to the D.C.P.R.S. buffer as timing is not at all critical. The baud rate can be increased to as high as 9600 baud if necessary.

C. SYSTEM SOFTWARE DESIGN AND OPERATION

The flow chart of the software programs used to process the recorded data of the RF noise measurement system is presented again in Figure 4.15. A description of each stage of the data processing is presented.

1. Digitize.com

The program Digitize.com is stored in the model 2764 EPROM located on the Vesta OEM188 single board computer. Control of the entire system is maintained by this program. Appendix A contains a copy of Digitize.com written in the higher level language BASIC. The computer samples the ten analog input signal levels sent from the interface amplifier assemblies with an 8-bit A/D converter at a specific time interval. The digitized

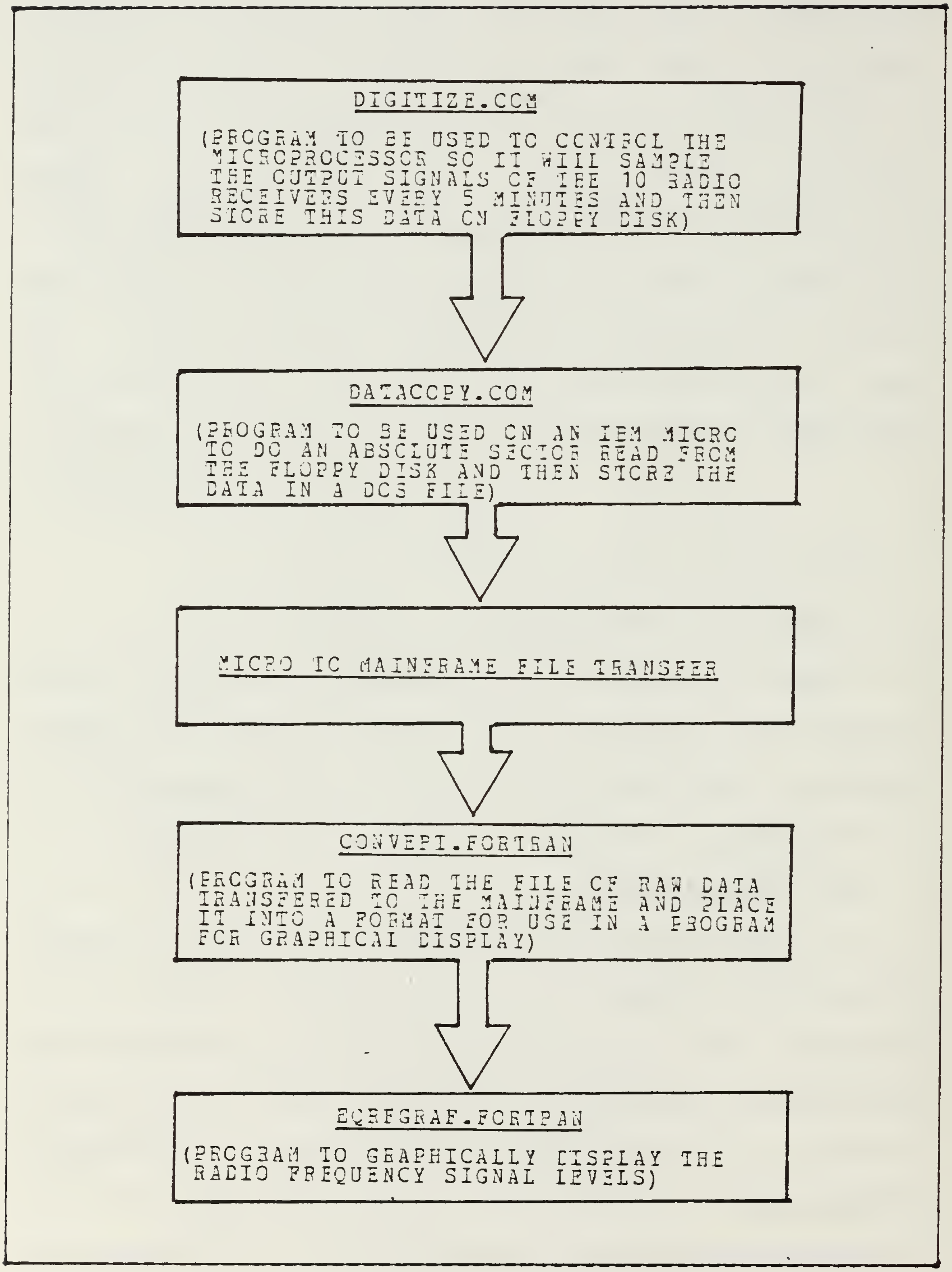

DIGITIZE.COM
(PROGRAM TO BE USED TO CONTROL THE MICROPROCESSOR SO IT WILL SAMPLE THE OUTPUT SIGNALS OF THE 10 RADIO RECEIVERS EVERY 5 MINUTES AND THEN STORE THIS DATA ON FLOPPY DISK)
DATACOPY.COM
(PROGRAM TO BE USED ON AN IBM MICRO TO DO AN ABSOLUTE SECTOR READ FROM THE FLOPPY DISK AND THEN STORE THE DATA IN A DOS FILE)
MICRO TO MAINFRAME FILE TRANSFER
CONVERT.FORTRAN
(PROGRAM TO READ THE FILE OF RAW DATA TRANSFERED TO THE MAINFRAME AND PLACE IT INTO A FORMAT FOR USE IN A PROGRAM FOR GRAPHICAL DISPLAY)
EQRFGRAF.FORTRAN
(PROGRAM TO GRAPHICALLY DISPLAY THE RADIO FREQUENCY SIGNAL LEVELS)

Figure 4.15 Data Processing Flow Chart

signal level data is then stored on magnetic disk. In addition, the data is sent to two external peripheral devices. The data is sent to a Data Collection Platform Radio Set buffer for eventual transmission over the satellite link and it is sent out to a monitor for visual display of the sampled signal levels.

The primary decision in the development of the program Digitize.com is the duration of the sampling interval used. There are two factors which must be satisfied in order to make the decision. The first is to ensure that enough samples are taken to accurately represent the signal levels. The desired outcome is to define long term variations in the background noise levels of the two VHF frequencies of interest, therefore the sampling may be spaced at intervals far enough apart to provide an overall trend, not necessarily every instantaneous fluctuation. The second factor involved in determining the sampling interval is available data storage space. Since there are 256 quantization steps for an 8-bit system, the analog signals are digitized and then represented at each sampling by a three digit number (100 to 355). For convenience in processing the data at a later time the data is stored in ASCII format, requiring 3 bytes of information for each sample of each signal level. With ten channels to be sampled at each interval this becomes:

3 bytes x 10 samples = 30 bytes/sample

The limiting factor is the storage space available on a magnetic floppy disk. A double-sided double-density floppy has 80 tracks on it for use. There are 9 sectors per track and 512 bytes per sector. The first sector of any disk cannot be used because it contains formatting information. Solving for the available storage space:

80 trks x 9 sec/trk x 512 bytes/sec - 512 = 368,128 bytes

If a two byte time stamp is added to the end of each sample to serve as a sampling period spacer there will be 32 bytes used at each interval. In this way the sectors will be evenly filled with 16 samples:

30 bytes/sample + 2 bytes/sample = 32 bytes/sample

512 bytes/sector / 32 bytes/sample = 16 samples/sector

Solving for the number of sectors available on a disk:

368,128 bytes / 512 bytes/sector = 719 sectors

The number of 32 byte samples which can be taken is:

368,128 bytes / 32 bytes/sample = 11504 samples

or, alternatively solving for this quantity:

719 sectors x 16 samples/sector = 11504 samples

The final decision to have a five minute sampling interval is a compromise between the amount of available data storage space and the desired degree of accuracy. This interval accurately represents the expected overall tendencies of the background noise levels and allows the following quantity of time for data storage:

5 min/sample x hr/60 min x day/24 hrs = 288 samples/day

11504 samples / 288 samples/day = 39.94 days of space

A special code to store the data in a specific location within a specific sector based on the actual date and time of the sampling period has been devised to create a sequential storage method for the data. Because of this, the time limit for storing the data on a disk is limited to the same time of the same day of the month following the insertion of the data disk or 31 days, whichever is least.

All of the sectors to be written to on the disk are accessed sequentially. To assign the current sector and location within the sector to which an absolute disk write operation is completed, the following calculations are made:

N = sample number

N = 12 * hour + minutes/5 + date*288

S = sector number

S = N / 16

P = data pointer to a specific location in the sector

P = MOD(N,16) * 32

The date, as well as the time in hours and minutes are obtained from the clock chip and the calculations are made for the write operation following each sampling interval. As a result, there is no overwriting of data for a month. Only up to a month of data for the ten sampled signal levels can be stored on a disk. It must then be removed from the noise recording system disk drive and a new blank formatted disk (using PCDOS 2.1 or later format) inserted to collect another month of data. It is important to note that the 32 byte data samples are stored on the disks by an absolute write. The data is not in a file structure and therefore cannot be observed on a computer at this time. It is not until the next step in the data processing is accomplished that the data can be observed by the user.

2. Datacopy.com

The program Datacopy.com as shown in Appendix B is the second stage of the data processing shown previously in Figure 4.15. The program is written using a public domain version of the higher level language FORTH and is stored on an IBM PCDOS 2.1 format disk as an executable file. The FORTH language was found to be the simplest and quickest means of accomplishing the desired outcome. Also stored on the same disk is an empty data file called Acquired.dat which will eventually store all of the data acquired on the data disk by the RF noise recording system. The purpose of the program Datacopy.com is to perform an absolute read operation on the data disk and then copy the data into the DOS file Acquired.dat. Once the data is in the DOS format file it is readily available to the user.

The transfer operation must be accomplished on an IBM Personal Computer with two disk drives booted with a DOS of version 2.1 or later. To perform the data transfer the following steps must be accomplished:

a. Place the disk with the two files Datacopy.com and Acquired.dat on it into disk drive "A" of the computer.

b. Place the data disk retrieved from the noise recording system woth up to a month of data on it into disk drive "B" of the IBM computer.

c. Type in the command "Datacopy Acquired.dat" at the system prompt. The program will direct the user from this point.

Data is transferred from the data disk in 1K blocks and the program continuously indicates how many "K" of data have been transferred into the file

Acquired.dat. The transfer can be stopped at any time by pressing any key. If a key is pressed the user will be left in the FORTH environment. To return to DOS, type in the command "bye". To transfer a complete month of data (278K) takes about 12 minutes. Once the operation is completed and the program has stopped transferring, press <CTRL>C or <CTRL> ALT DEL. The entire contents of the file Acquired.dat can be observed by entering the command "type Acquired.dat". The data is now stored in a DOS file format and the user is ready to proceed with the next step of the data processing.

3. Micro to Mainframe File Transfer

To allow for greater versatility and storage capability, the DOS file Acquired.dat created by Datacopy.com is sent to the IBM 3033 host computer using the 3270 terminal mode file transfer technique. The 3270 terminal mode file transfer is a method of file transfer that can only be used when the PC is operating as a 3278 model 2 display terminal and is connected to an IBM host computer running either SIM3278/VM or SIM3278/VTAM [Ref. 13:p. 8-7]. To perform a 3270 terminal mode file transfer the IBM PC to be used must be connected to either SIM3278/VM or SIM3278/VTAM on the host computer. A number of IBM personal computers with this capability are located at the Naval Postgraduate School. Reference 13 provides complete documentation on the file transfer process.

Using a terminal meeting the required specifications the command "send Acquired.dat Acquired Data A1 (ASCII crlf" is entered. The disk with the file Acquired.dat containing the signal level data must be in the PC disk drive. The PCDOS file Acquired.dat is transferred to the users "A" disk into a file designated as FN FT Acquired Data. The data will be sent sequentially to the file in the order of the days of the month, i.e., from the date 01 to the date 31. If during any of these days there was no data collected, the file will be blank at that point.

4. Convert Fortran

Upon the completion of the microcomputer to host computer file transfer, the next step in the processing of the data is to rearrange or "convert" the data in the newly created acquired data file into a more convenient format. The program Convert Fortran as shown in Appendix C is designed to accomplish this. Once the data is rearranged by this program it can be used as a hardcopy sequential record of the signal level data. The new format will also allow for plotting of the data using DISSPLA (Display Integrated Software System and Plotting Language).

One month of data transferred to the main frame file Acquired Data is approximately 3900 lines in length. The 30 character segments of data (10 channels of data with 3 digit characters used to represent each signal level, i.e., 100 to 355) are written consecutively into the 80 character per line file. Each 30 character data segment is separated by a two character spacer (00, 01, 02, 03, 04, or 05). The program Convert Fortran will read the 30 character segments one at a time out of the Acquired Data file, assign a sequential number, then write them to the new file. The following steps must be followed to accomplish the rearrangement:

a. Change the FN FT of Acquired Data into FN FT File FT08F001 and save this newly named file.

b. Ensure that the variable named ISTART in the program Convert Fortran is assigned the correct numerical value. ISTART is determined by the amount of data characters from the last 30 character segment in the second row of the data file Acquired Data which have not overflowed with the rest of the segment onto the next line. An example is presented in the system performance section of this thesis.

c. Run the program Convert Fortran and save the rearranged datafile by issuing the following sequence of commands at the appropriate times:

   - "Fortvs Convert"
   - "Record on"
   - "Load Convert(start"
   - "Record off"

d. Temporarily store this new sequentially arranged data in any FN FT. Delete any extraneous entries from the file so that only the sequential numbering and data remains in it.

e. Erase the file previously designated File FT08F001 in Step a. (the original is still in the file Acquired Data).

f. Change the FN FT of the file created in
   Step d. to File FT08F001.

Once these steps are completed the user has a sequentially arranged file of the 30 character segments obtained during each sampling interval. A copy of this can be obtained by the command "print". The data in File FT08F001 is also prepared for the final stage of the data processing.

5. Eqrfgraf Fortran

In this final step of the data processing a graphical representation of the data in File FT08F001 created by Convert Fortran is obtained. The user must be located at a terminal with an attached Tektronic 618 graphics monitor to run the program Eqrfgraf Fortran shown in Appendix D.

Once the necessary minor modifications are made to the program Egrfgraf Fortran to provide the desired output , the following commands are issued:

```
"Fortvs Eqrfgraf"
"Disspla Eqrfgraf"
```

A plot of the selected channel(s) of data is displayed on the Tektronic 618 monitor. A hard copy of the graphs may be obtained at this time.

D. SYSTEM PERFORMANCE

A listing of selected calibration settings for the input radio frequency signal strengths in microvolts to the corresponding analog to digital converter input voltage levels and quantized signal levels is shown in Table V. The system was placed into operation in November of 1986. The input signals were sampled and recorded on magnetic disk. The data recorded directly onto the disk was transferred to the DOS file Acquired.dat. Completing the next required step of data processing, the DOS file was transferred to the main frame and stored in the file Acquired Data. A copy of a portion of this file is shown in Figure 4.16. The program Convert Fortran rearranged the data into the sequential format file called File FT08F001 as shown in Figure 4.17. The final step of data processing was completed by running the program Eqrfgraf Fortran and the plots obtained are shown in Figures 4.18 to 4.27.

TABLE V

SYSTEM PERFORMANCE LEVELS

Input RF signal level to the receivers (microvolts)	Corresponding input voltage level to the A/D converter (volts)	Corresponding quantized signal level stored in data file (unitless)
0.0	0.00	100
1.0	0.32	116
2.0	1.00	151
3.0	1.77	190
4.0	2.49	227
5.0	3.07	257
6.0	3.57	282
7.0	3.98	303
8.0	4.36	322
9.0	4.68	339
10.0	5.00	355

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000269307287228284156229278275331 42333122792282921
59225238271327 5254300276204284150218270257287 5247295259228287100214270267285 0
231291232228275147209231263282 5232283243228276100205267272282 12342962392282671
33203260259279 1223287225196262100200252260276 2228283230196248133195257255276 2
227234236196237135194254255275 3228278231196255125195252232275 32242832031962531
32192253254256 4223280236180253123191246251273 4225275234196254128175247250271 5
226273239196255131175248251271 5221276242196234131187247252267 02192752321962521
04190241255271 5225276199196250131189250253253 1222276223196241132188248253259 1
225275240196236131186246251271 2223276240196233131187245253265 22202782401962331
30186245252265 3198271232196249136190215253269 3217275232196252100189239256269 4
216280234196248100188239253268 4221276235196228129185244252269 52202592351962481
28179245242269 5218275216196248132187221253266 0221269234196253127170243250269 5
221275235196227129186242250267 1221276244196238129186243251269 12232722031962481
28186248253251 2195276230196248127188217254267 2207273229196247136186207256267 3
223264235196249127175244248269 3196270229196252131189213253266 42202762321802501
20187242255269 4197278229196249135188211253268 5221275240196231129184244252272 5
225261235196251126177245246269 0221271236196250133175242249269 52222762301962361
28187245252259 1221275240196237130182244251270 1201279230196251136189205253268 2
205278232196251136188204254268 2220275232196253132171246249270 32212712331962521
00189240255270 3198277231196253121191220252269 4219279232196255100189240256269 4
224273236180249123190246243270 5224276210196251135189225255266 52232782331962511
35176246251271 0226283206196250136188235256263 5218276227196251100190240253270 1
209277228196253136189206254269 1226275195196251132188251256256 22282742331802561
27191244238273 2220280232196255100190241254271 3209278233196254100190240253270 3
224281236180250125190250249273 4221276231196256100190241257272 42002742301962541
35192216254270 5225275236196257136177247251273 5227267233196256128192247222272 0
207283228196251138192212255270 5227273236196251138181248251273 12012762281962551
31192222256270 1217279224196252138189217256270 2210280227196254140192210255270 2
201280235196256131193218261271 3229279231196258133175249251273 32292642321962571
35187252244273 4204277231196253127194224255271 4228276232180257127192248257274 5
229284215196254137191254253256 5218285231196257100194250256272 02292842311962591
36176250252274 5225283235196239137192250256271 1220280231196259100194250257273 1
229268233196259135193254235273 2230282235196236137192248256272 22052842261962591
27195228257273 3232269230196260136191253237274 3224284222196258142193219256272 4
231281229196262136176252256275 4226283214196257141193230258272 52262842121962581
43194227257273 5232280236196246137190250255276 0233289196196258138194255257260 5
232281227196261135177251254276 1233283228196263138177255258275 12072812311962591
44196221259273 2234287207196259140195230258274 2233283208196259141195232258274 3
236289228180263136196250261276 3212286222196262111196244257274 42342782271962641
41181252254276 4237287196196257141196257258260 5231284228196263100197252258276 5
235283232180261132196253253278 0207291225196263139197224259276 52342852111962551
40195257256257 1233288203196261143196255257258 1232284224180264134197250262276 2
236288199196263141196259258259 2209288228196265145197224260277 32332752281962651
37199252228278 3234288225196251143195254259266 4234290224196266116200250259276 4
234291227196248142195253261267 5209291228196266147199224260276 52322912271962651
24199255261278 0237291209196260143199239260274 5238279231196265137183256260277 1
235286220196254142197255260266 1235290227196252143197254260266 22362902281802661
38199252263279 2232292228196267108202252262280 3238292204196263142200239260273 3
221292231196267128199245267276 4238284207196262143199259257260 42372872351962671
06201252260278 5236268236196266142195256242281 5214286236196265147199228262277 0
213286228196265150200230261276 5220298233196267117199253261277 12272962351962671
50200215261277 1240295200196266144200259259264 2213292235196267149200222262276 2
243283236196268140201254229279 3239282240196271142183256259279 32402882401962691
44187258257279 4241297210196266145199261259260 4240288242196259147193265258280 5
222300242196267149199216262278 5240287235196269146188260261279 02392912131962641
43200262259260 5241292211200266146201245262272 1242284242196257146199257262280 1
220292237196270131202247261278 2240286242196269143184257262279 22372892391962711
09202255261281 3238295241196270109202251261279 3216292238196269131202240261278 4
233300232196268151202217262279 4241296243196272140201257247281 52152912372282701
45203233264279 5239300244196248145200256260277 0243236244196271143201258242280 5
243292210196266146202253263268 1218299242228269143202236263280 12412842541962691
45197257252280 2229296245196270152204217263277 2240291240228271112202256263281 3
```

Figure 4.16 Sample Acquired Data File

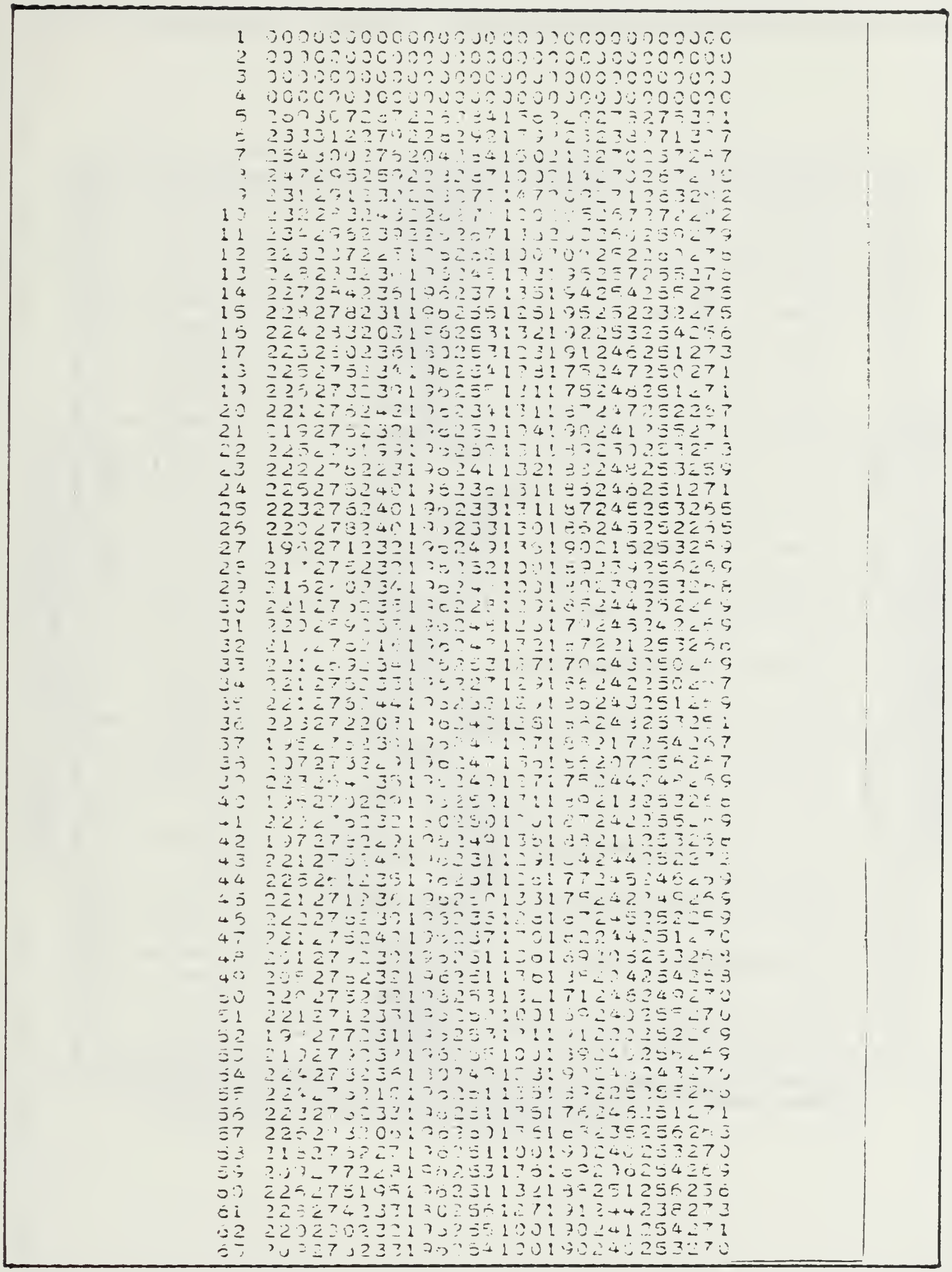


Figure 4.17 Sample File FT08F001 File

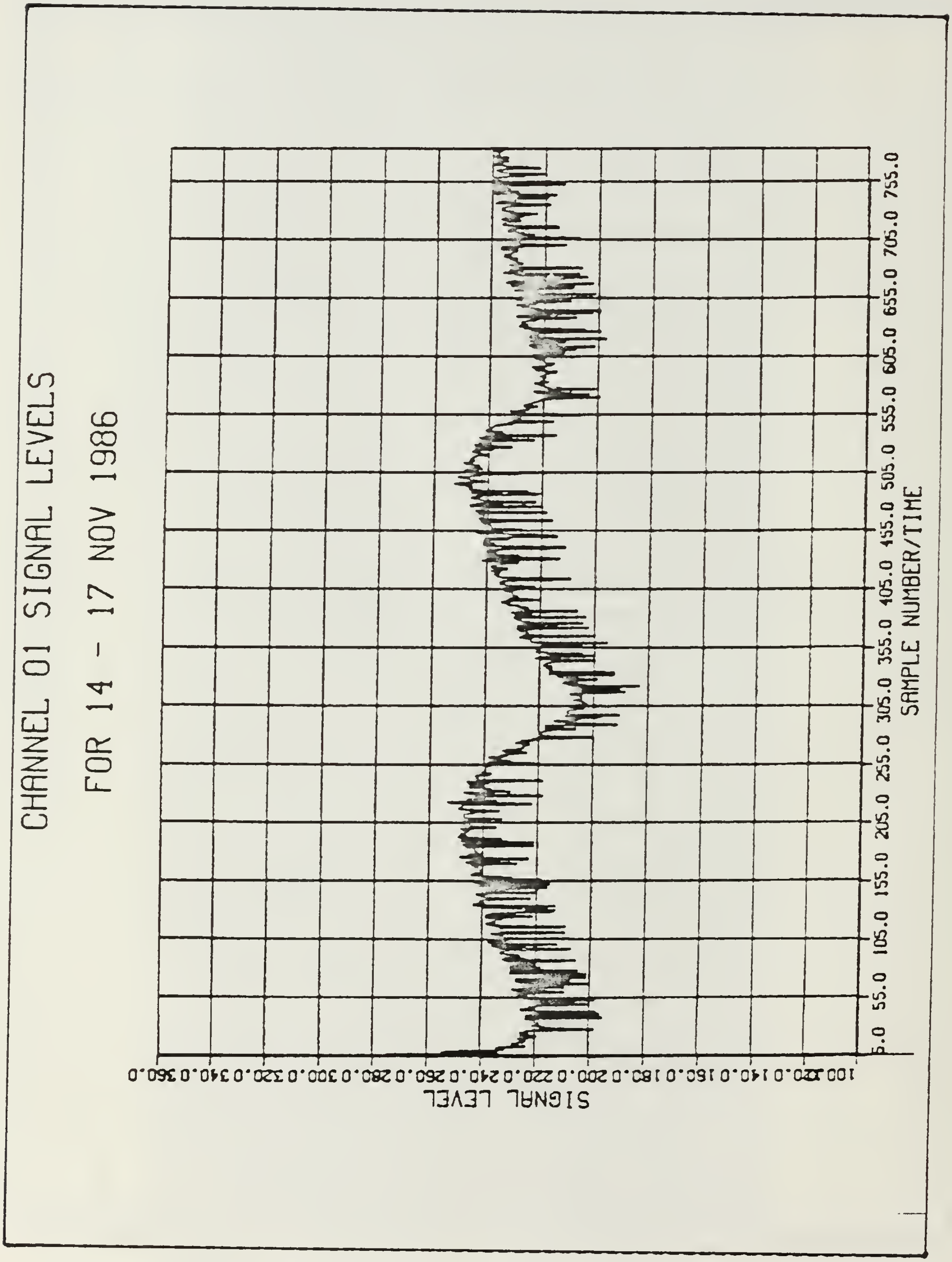


Figure 4.18 Channel 01 Signal Levels

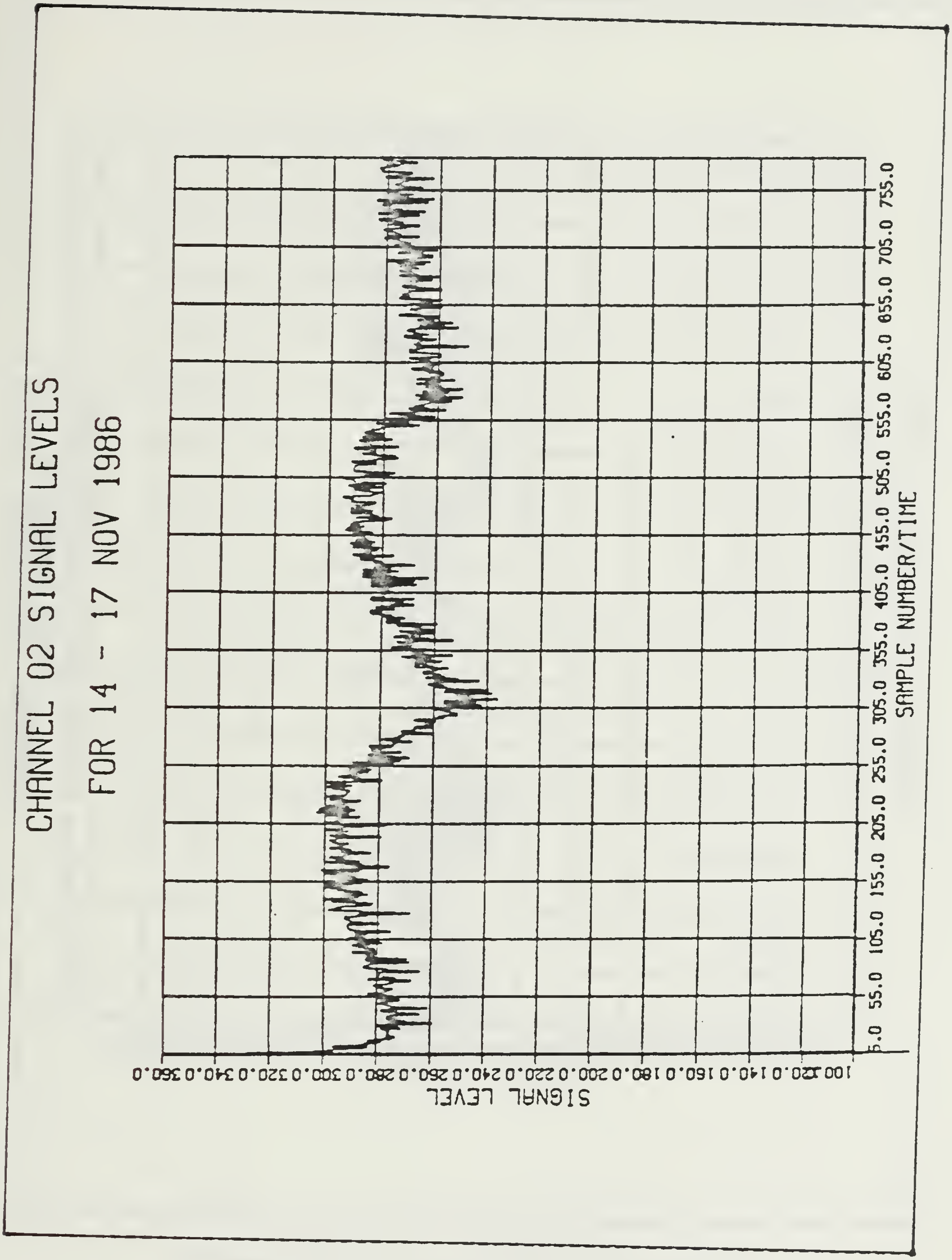


Figure 4.19 Channel 02 Signal Levels

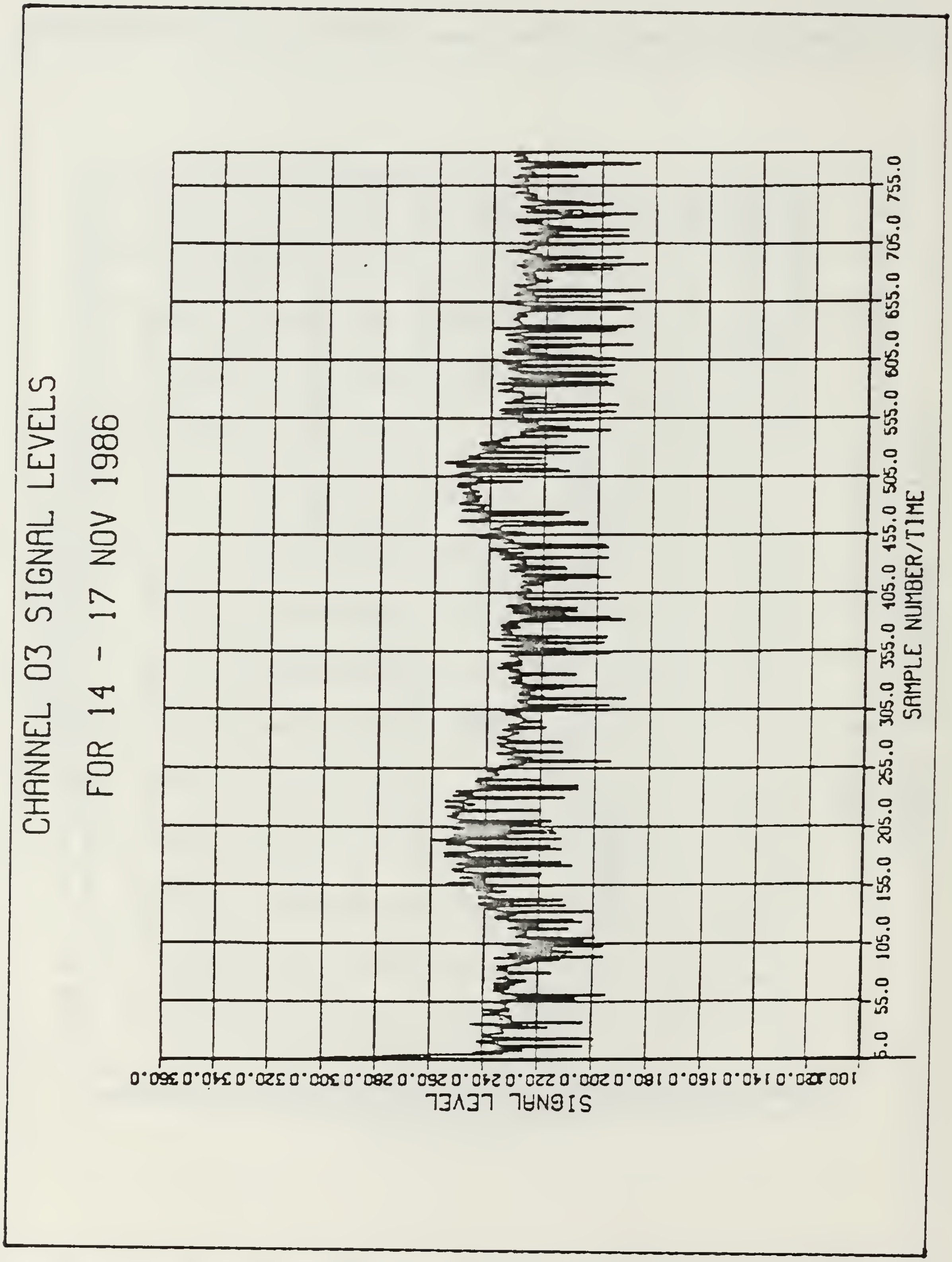


Figure 4.20 Channel 03 Signal Levels

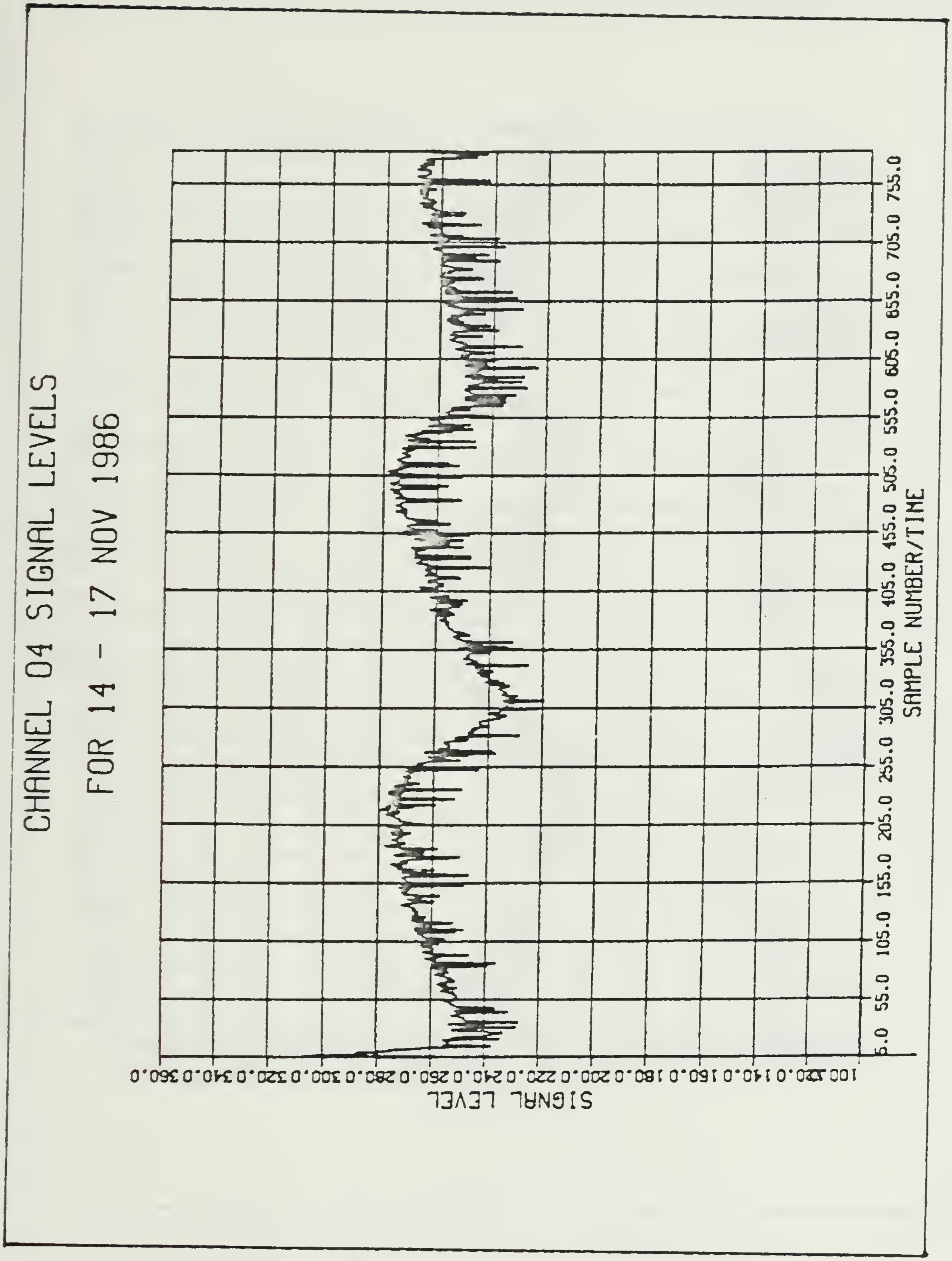


Figure 4.21 Channel 04 Signal Levels

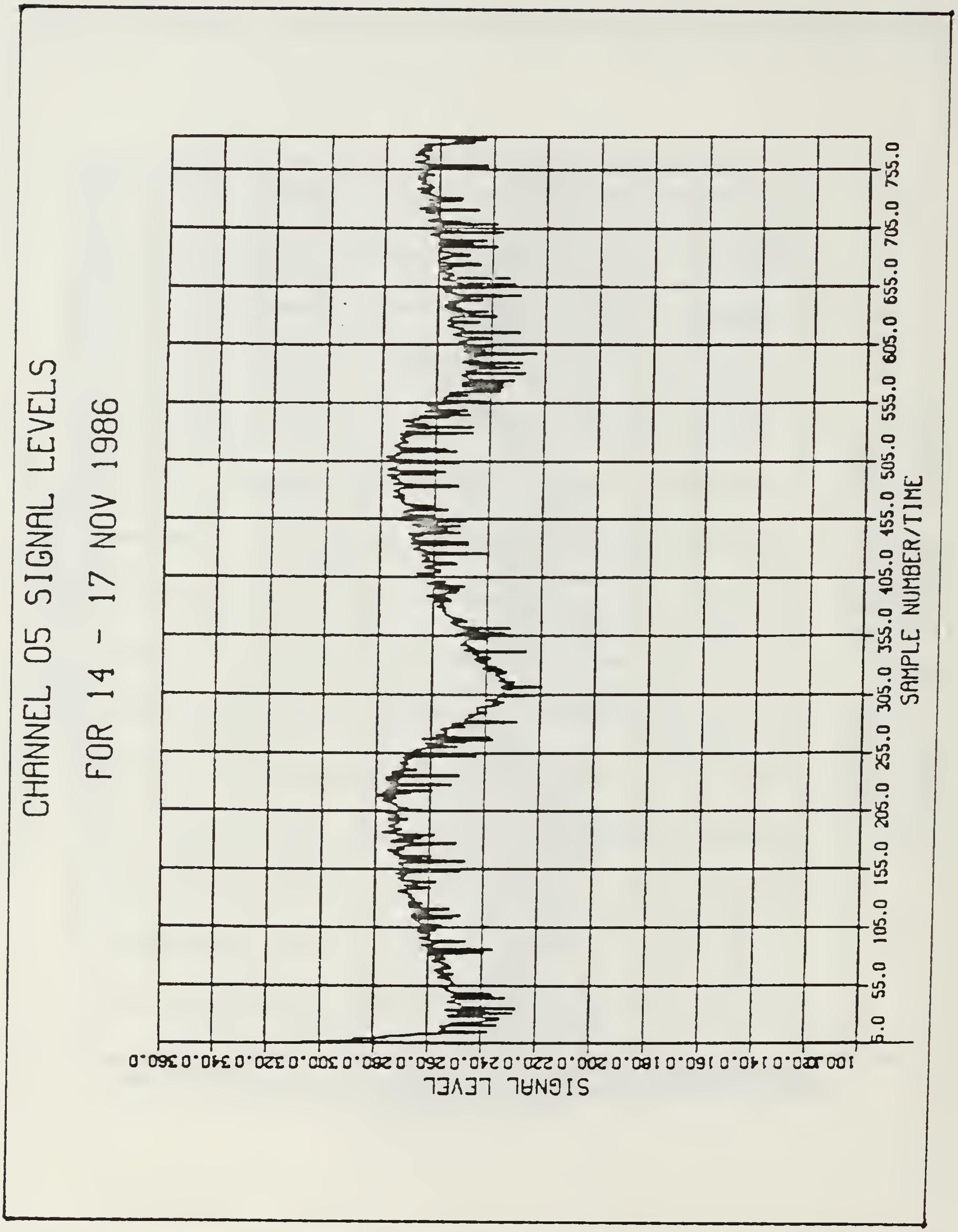


Figure 4.22 Channel 05 Signal Levels

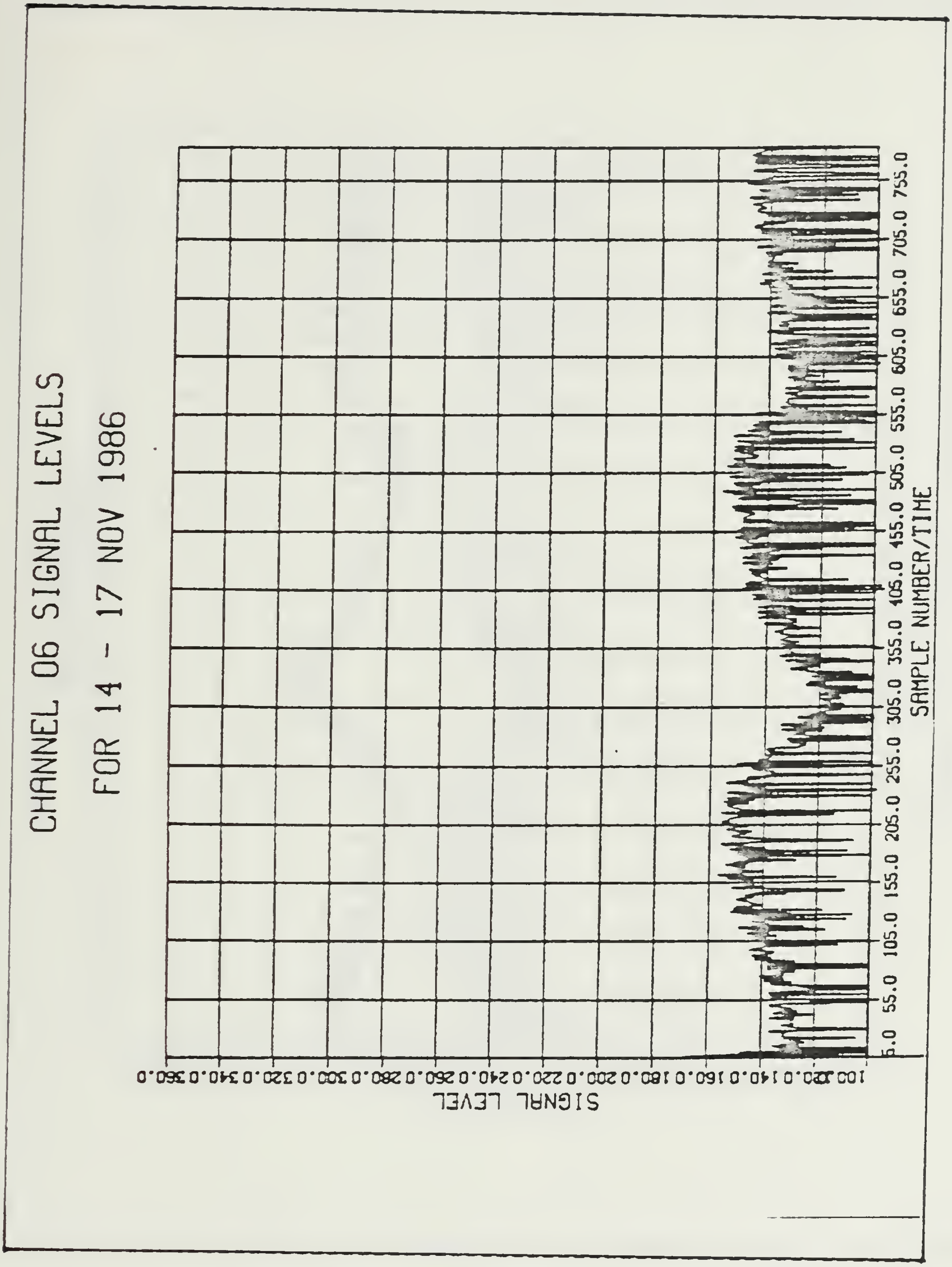


Figure 4.23 Channel 06 Signal Levels

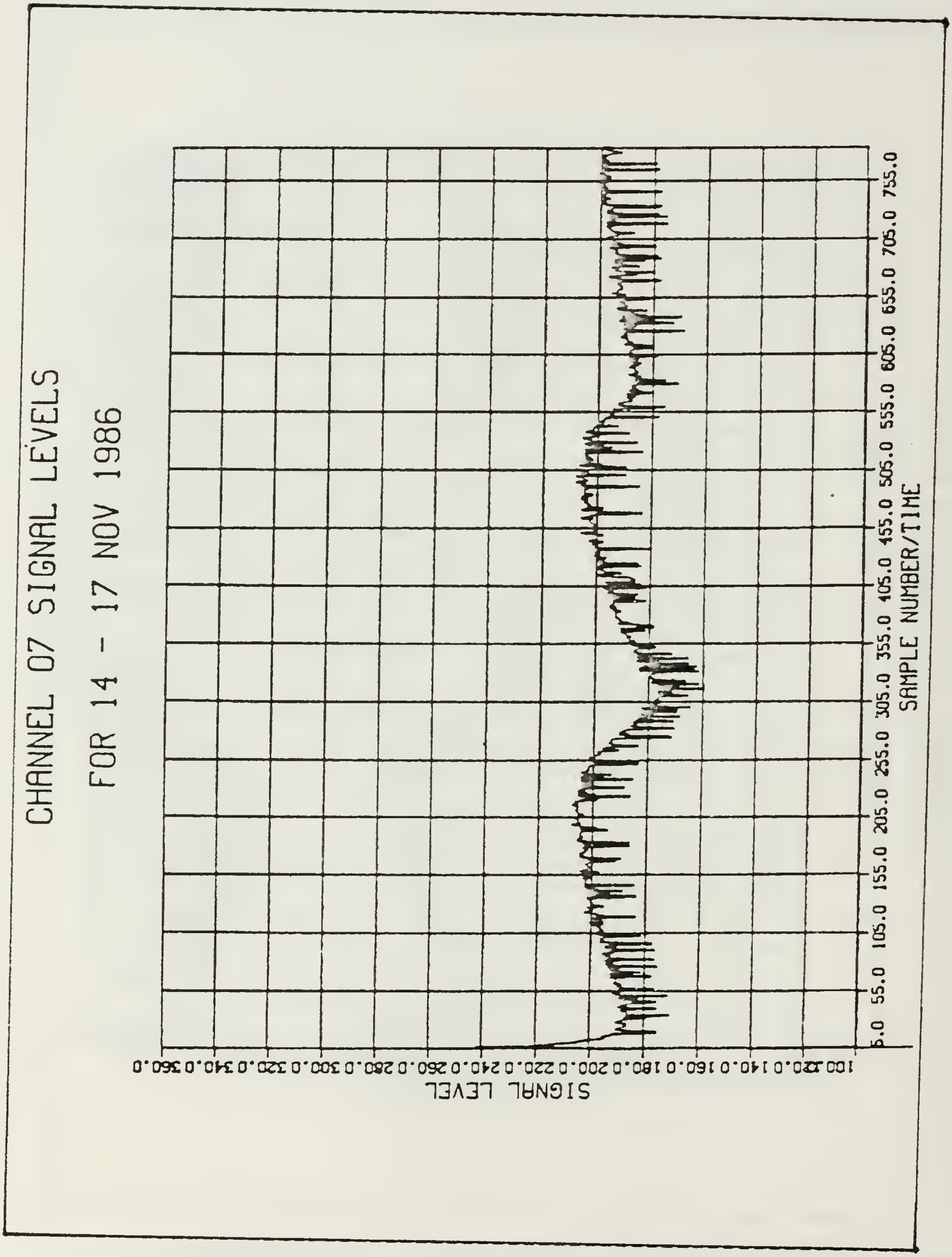


Figure 4.24 Channel 07 Signal Levels

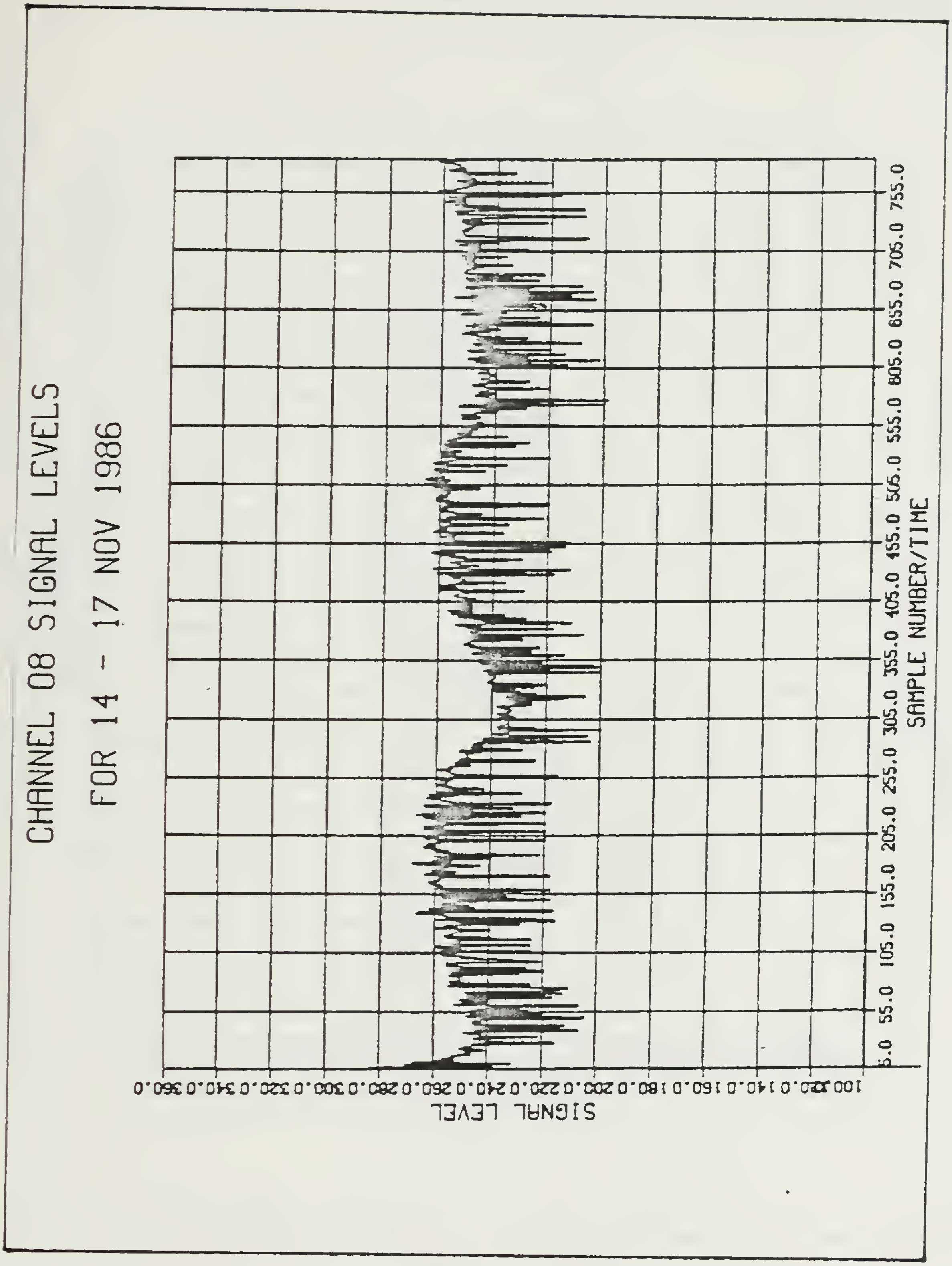


Figure 4.25 Channel 08 Signal Levels

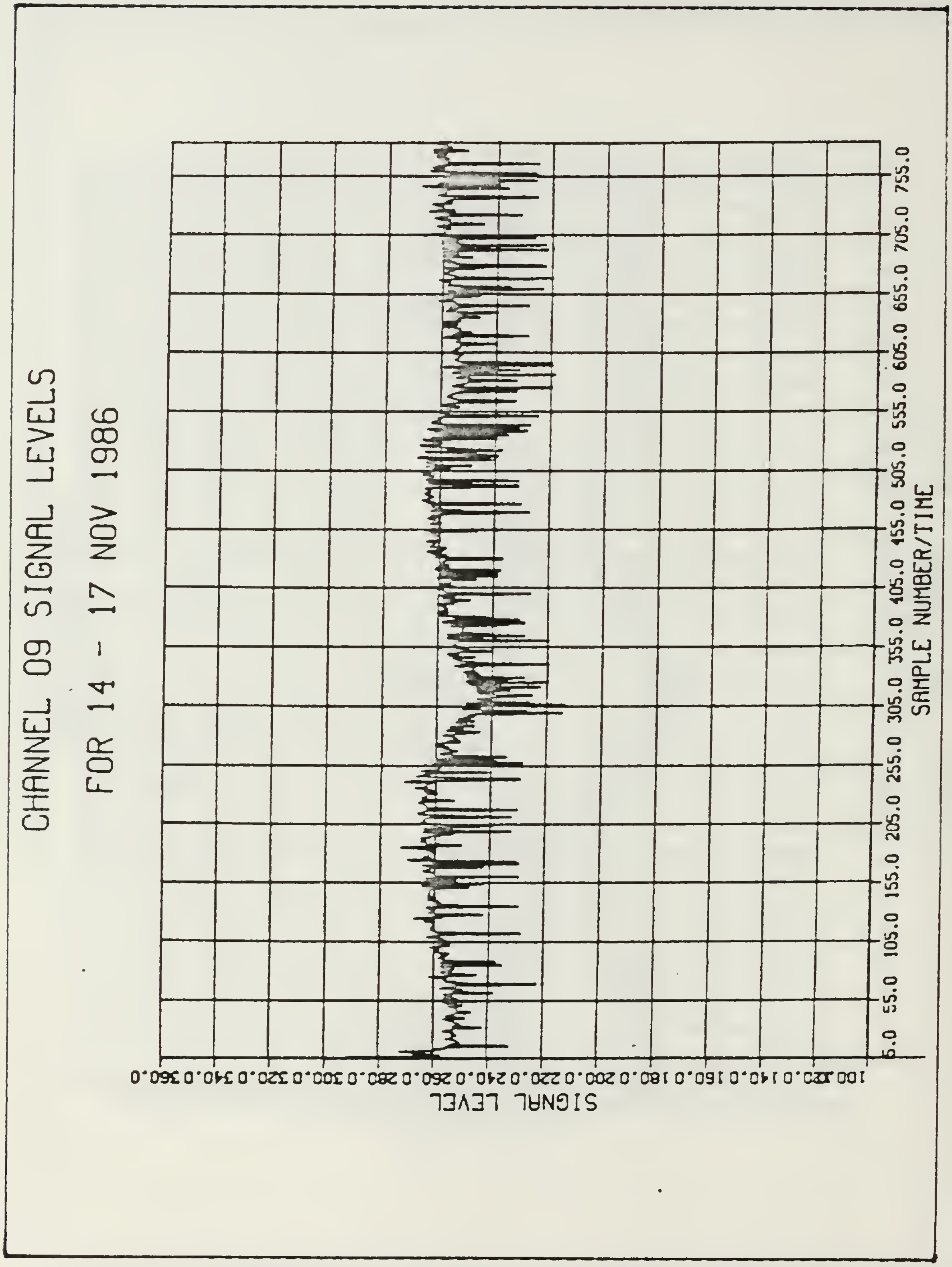


Figure 4.26 Channel 09 Signal Levels

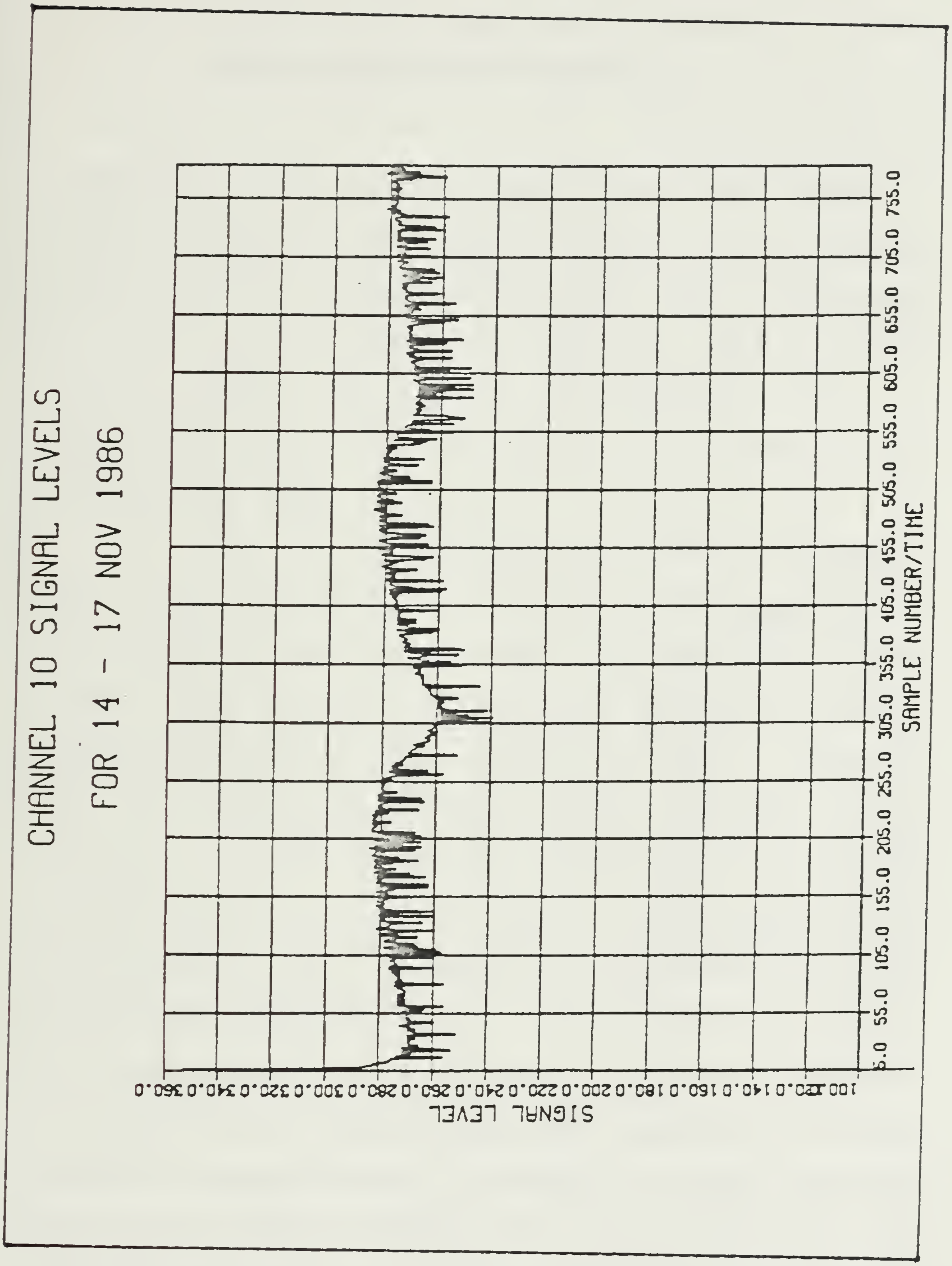


Figure 4.27 Channel 10 Signal Levels

V. RECOMMENDATIONS AND CONCLUSIONS

A. RECOMMENDATIONS

There are several avenues of research to be pursued which could provide further correlation between precursory radio frequency emissions and earthquake activity. By utilizing the present design of the VHF noise measurement and recording system, several modifications to the hardware and software may provide more explicit results. Limitations would of course be related to the available funding.

The range of frequencies to be monitored for activity could be vastly increased by the introduction of a scanner receiver in place of the ten fixed-range receivers. There are a large number of commercial grade scanner receivers capable of measuring signals in the KHz range to as high as the GHz range. Many of them are fully programmable, allowing the user to select a large number of channels to be scanned. The scanning of the signals at the selected frequencies would need to be synchronized to the sampling rate of the analog to digital converter. This would require the design of external digital circuitry. By incorporating a log-periodic antenna array and a wideband amplifier into the system with the scanner receiver, a much wider band could be monitored for radio frequency activity.

An increase in the measurement accuracy of the VHF signal levels being monitored could easily be achieved by increasing the sampling rate. A simple software modification to the program Digitize.com would accomplish this. However, the increased sampling rate would also require having a much larger data storage capability. The use of hard disk drives, or even magnetic bubble memory units for data storage would accommodate the increased signal sampling rate, but the expense involved must be considered.

Now that the recorded data is in a very manageable form, the potential for much more detailed long range data analysis exists. Programs to examine the recorded signal level data could be created to perform a number of mathematical operations. It will be important to search the data over a long period of time to determine routine patterns and cycles. Once a firm data base has been established, the ability to distinguish any unusual disturbances may provide a deeper understanding of the phenomena being observed.

B. CONCLUSIONS

The design, construction and implementation of the computer controlled radio frequency noise measurement and recording system for detection in the 30.45 MHz and 150.75 MHz range provides a means of analyzing acquired data rapidly and accurately. The interfacing of this system to a digital satellite link adds a reliable remote sensing capability. Future analysis of the data may enhance the potential for using radio frequency emissions as a precursor to future earthquake activity.

At the present time more research is required to establish a correlation between radio frequency emissions and earthquake activity. To overcome the credibility gap which presently exists in the use of RF emissions as a precursory device, a detailed documentation of the acquired data must be accomplished. In this way, a basis for future predictive capability can be established. Several criterion need to be identified to determine radio frequency precursory anomalies. First, the day to day normal activity pattern must be clearly and quantitatively defined by extensive sampling of the background noise activity. Second, the anomalous RF activity has to be defined quantitatively and then evidence shown that the "anomaly" was significant or unique. Third, a physical or casual link between the RF anomaly detected and an actual earthquake must be established. In this way the radio frequency emissions may then be absolutely defined as precursory.

APPENDIX A

DIGITIZE.COM COMPUTER PROGRAM

```
                *************************************
                * PROGRAM USED TO CONTROL THE       *
                * MICROPROCESSOR TO SAMPLE THE OUTPUT*
                * SIGNALS OF THE 10 RADIO RECEIVERS  *
                * EVERY 5 MINUTES, STORE THE DATA    *
                * ON MAGNETIC DISK AND SEND THE DATA *
                * TO A D.C.P.R.S. BUFFER.            *
                *************************************

DISK CALCULATIONS:

9SEC/TRK X 512 BYTE/SEC X 80 TRK - 512 = 368,128 BYTES.  (CAN'T USE
FIRST SECTOR, IT CONTAINS SYSTEM AND FORMATTING INFORMATION)

3 BYTES X 10 SAMPLES  = 30 BYTES/SAMPLE.  (DATA WILL BE STORED AS 3
ASCII NUMBERS RANGING FROM 100 TO 355, NO INTERDATA MARKERS)

LAST 2 BYTES IN EVERY SAMPLE WILL BE USED AS A SAMPLING PERIOD
SPACER RESULTING IN 32 BYTES/SAMPLE

512 BYTES/SEC / 32 BYTES/SAMPLE = 16 SAMPLES/SECTOR

24 HR/DAY X 60 MIN/HR X 1/5 SAMPLE/MIN = 288 SAMPLES/DAY

288 SAMPLES/DAY / 16 SAMPLES/SEC = 18 SEC/DAY

FROM BASIC, ALL SECTORS ARE ACCESSED SECUENTIALLY, 0 - 1279. TO
FIND CURRENT SECTOR AND LOCATION IN CURRENT SECTOR THE FOLLOWING
CALCULATIONS ARE MADE:
SAMPLE NUMBER N = 12*HOURS + MINUTES/5 + DATE*288
SECTOR NUMBER S = N/I6
DATA POINTER  P = MOD(N,16)*32

VARIABLES:

A    AN ARRAY OF 10 SAMPLED INPUTS
B    BUFFER FOR DISK SECTOR, LOCATED AT ADDRESS 1800H
C    ASCII CONVERSION BUFFER, LOCATED AT ADDRESS I700H
D    DATE,1-31
H    HOURS,0-23
I    GENERAL COUNTER
J    GENERAL COUNTER
M    MINUTES,0-59
N    SAMPLE NUMBER, FUNCTION OF THE DATE AND TIME OF DAY
P    POINTER INTO SECTOR, FUNCTION OF TIME OF DAY
S    SECTOR NUMBER, FUNCTION OF DATE
T    TIME OF DAY,  0000-2359
U    OLD TIME OF DAY
Y    TEMPORARY STORAGE VARIABLE
Z    TEMPORARY STORAGE VARIABLE
```

```
MAIN PROGRAM:

1000 GOSUB 9000:REM INITIALIZATION ROUTINES
1100 GOSUB 2000:REM WAIT FOR 5 MINUTE DATA TIME
1120 GOSUB 3000:REM GET 10 SAMPLES
1140 GOSUB 4000:REM CONVERT 10 SAMPLES TO ASCII
1200 READ(B,S): REM READ SECTOR FROM DISK INTO MEMORY
1220 GOSUB 5000:REM PUT NEW ASCII IN BUFFER
1300 WRITE(B,S):REM WRITE BUFFER BACK TO DISK
1500 GOSUB 7000:REM VERIFICATION OF SAMPLING CRITERION
1600 GOSUB 8000:REM OUTPUT CHANNEL DATA TO TERMINAL/D.C.P.R.S.
1900 GOTO 1100: REM LOOP

2000 REM - WAIT FOR 5 MINUTE INTERVAL AND CALCULATE CURRENT SECTOR
2100 T=CLOCKREAD:REM                GET NEW TIME
2120 IF(T=U) GOTO 2100:REM          IS OLD TIME=NEW TIME
2140 U=T:REM                        UPDATE OLD TIME
2200 IF(MOD(T,5)<>0) GOTO 2100:REM  NOT 5 MINUTE INTERVAL
2300 M=MOD(T,100):REM               CALCULATE MINUTES
2310 IF(M=60) GOTO 2100             PREVENTS DOUBLE SAMPLE ON HR
2320 H=(T-M)/100:REM                CALCULATE HOURS
2400 D=INP(%E208) AND 15 + 10*(INP(%E209) AND 15):REM OBTAIN DATE
2600 N=H*12+M/5+D*288:REM           CALCULATE SAMPLE NUMBER
2620 S=N/16:REM                     SECTOR NUMBER
2640 P=MOD(N,16)*32:REM             POINTER TO DATA IN SECTOR
2990 RETURN

3000 REM - GET 10 SAMPLES INTO  A  ARRAY
3050 A=%1000
3100 FOR I=0 TO 9:REM               10 SAMPLES
3120 OUT(%30,I):REM                 SET UP MUX AND START CONV
3140 A(I)=INP(%30):REM              READ RESULT
3160 NEXT I

4000 REM - CONVERT SAMPLES TO ASCII FORMAT
4100 FOR I=0 TO 41:REM              FILL BUFFER WITH 42 SPACES
4120 POKE(C,%20):REM                ASCII SPACE
4140 NEXT I
4200 FOR I=0 TO 9:REM               NOW CONV AND MOVE 10 SAMPLES
4240 GEN(C+I*4,(A(I)+100):REM       INTO  C  BUFFER (RANGE:100-355)
4260 NEXT I:REM                     FINAL <CR> STILL IN BUFFER
4990 RETURN

5000 REM - MOVE NEW SAMPLES INTO DISK BUFFER AREA IN RAM
5100 FOR I=1 TO 3
5101 DPOKE(B+P+(I-1),DPEEK(C+I))
5102 NEXT I
5103 FOR I=5 TO 7
5104 DPOKE(B+P+(I-2),DPEEK(C+I))
5105 NEXT I
5106 FOR I=9 TO 11
5107 DPOKE(B+P+(I-3),DPEEK(C+I))
5108 NEXT I
5109 FOR I=13 TO 15
5110 DPOKE(B+P+(I-4),DPEEK(C+I))
5111 NEXT I
5112 FOR I=17 TO 19
5113 DPOKE(B+P+(I-5),DPEEK(C+I))
5114 NEXT I
```

```
5115 FOR I=21 TO 23
5116 DPOKE(B+P+(I-6),DPEEK(C+I))
5117 NEXT I
5118 FOR I=25 TO 27
5119 DPOKE(B+P+(I-7),DPEEK(C+I))
5120 NEXT I
5121 FOR I=29 TO 31
5122 DPOKE(B+P+(I-8),DPEEK(C+I))
5123 NEXT I
5124 FOR I=33 TO 35
5125 DPOKE(B+P+(I-9),DPEEK(C+I))
5126 NEXT I
5127 FOR I=37 TO 39
5128 DPOKE(B+P+(I-10),DPEEK(C+I))
5129 NEXT I
5130 GEN(B+P+30,M)
5990 RETURN

7000 E = CLOCKREAD
7010 F = 10*(INP(%E20B) AND 15) + INP(%E20A) AND 15
7020 G = 10*(INP(%E209) AND 15) + INP(%E208) AND 15
7030 Y = 10*(INP(%E20D) AND 15) + INP(%E20C) AND 15
7100 PRINT "8 BIT A/D SIGNAL LEVELS FOR:",E,":",F,"  /",G,"  /",Y
7200 RETURN

8000 FOR I=0 TO 9:REM                SEND DATA TO MONITOR
8010 PRINT "CHANNEL",I+1," DIGITIZED SIGNAL LEVEL:",A(I)+100
8015 PRINT " "
8020 NEXT I
8030 PRINT "**************************************************"
8050 COMINIT(110,2,0,1):REM          INITIALIZE OUTPUT PORT
8055 FOR I = 0 TO 9
8057 Z = A(I)                        SEND BINARY DATA OUT OF
8060 Y = COMOUT(Z):REM               PORT 4 (P4) TO THE D.C.P.R.S.
8065 NEXT I
8100 RETURN

9000 REM - INITIALIZATION CODE
9100 U=0:REM                         SET OLD TIME TO IMPOSSIBLE VALUE
9120 C=%1700:REM                     ASCII CONVERSION BUFFER
9140 B=%1800:REM                     BUFFER FOR DISK DATA
9990 RETURN
32000 STOP
```

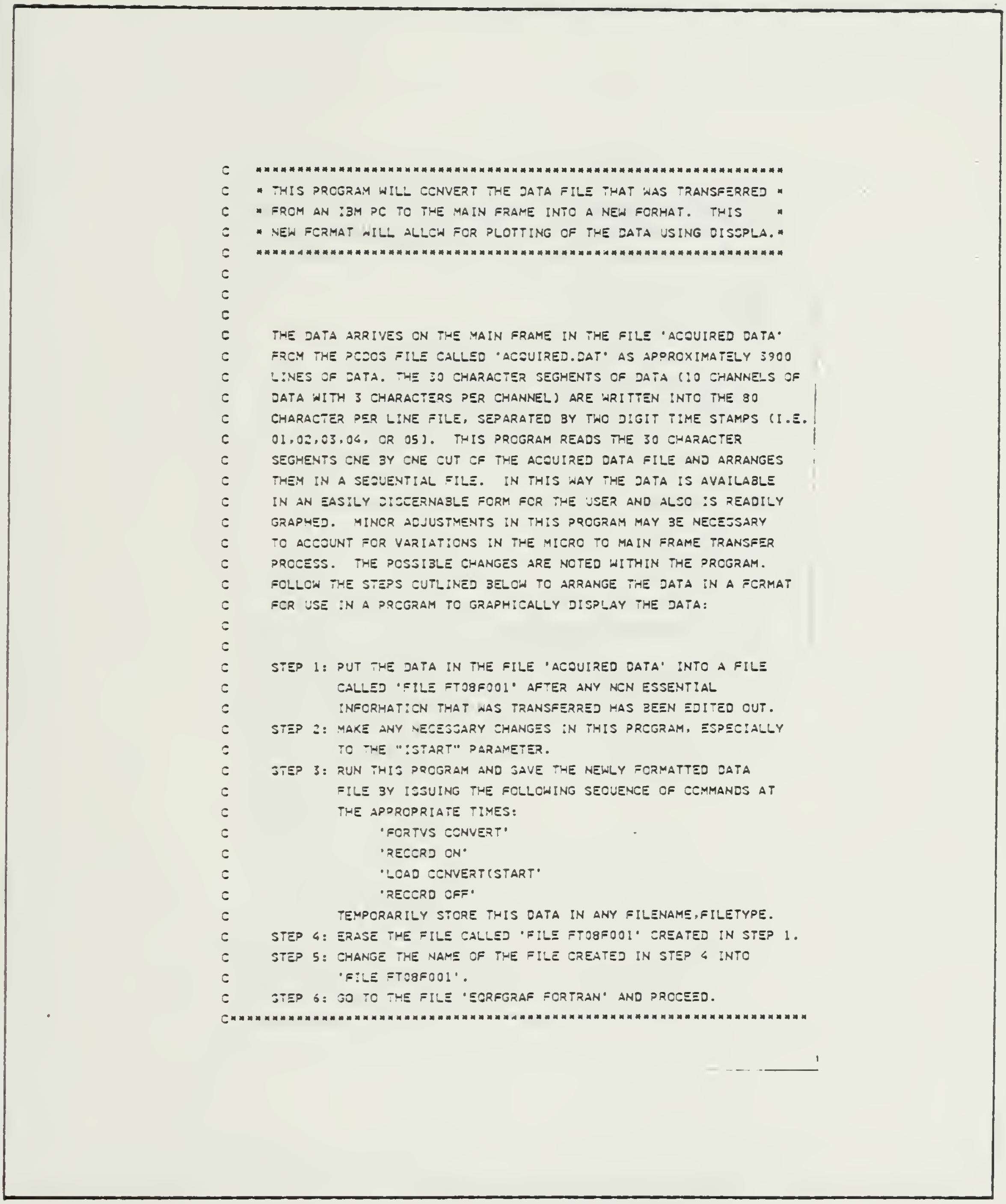
APPENDIX B

DATACOPY.COM COMPUTER PROGRAM

```
                ****************************************
                * PROGRAM TO BE USED ON AN IBM MICRO *
                * TO DO AN ABSOLUTE SECTOR READ FROM *
                * THE MAGNETIC DISK AND THEN STORE   *
                * THE DATA IN A DOS FORMAT FILE.     *
                ****************************************

/ DATACOPY PROGRAM

1 3 +THRU               / LOAD IN THE PROGRAM CODE
' DO-IT IS BOOT         / SET UP FOR AUTO-RUN
SAVE-SYSTEM B:DATACOPY.COM

/ DISK INTERFACE VIA BIOS
CODE INT13         (S OFFSET SECTOR# OP -- F )
   DI POP  AX POP  DX DX XOR  720 # BX MOV  BX DIV  AX PUSH
   DX AX MOV  DX DX XOR  BX SHR  BX DIV  BX POP  AL BH MOV
   DX AX MOV  9 # CL MOV  CL DIV  AH AL XCHG  AX INC
   AX CX MOV  BX DX MOV  BX POP  DS PUSH  ES POP  DI AX MOV
   AH AL XCHG  1 # AL MOV  SI PUSH  BP PUSH  19 INT
   0 # AX MOV  U< IF AX DEC THEN  BP POP  SI POP  1PUSH
   END CODE
CODE SETUP         (S BUFFER OP -- OFF1 SEC1 OP OFF2 SEC2 OP )
   DX POP  BX POP  0 [BX] AX MOV  4 [BX] CX MOV  AX SHL
   CX PUSH  AX PUSH  DX PUSH  512 # CX ADD  AX INC
   CX PUSH  AX PUSH  DX PUSH  NEXT  END CODE
:  RBIOS   2 SETUP INT13 >R INT13 R> OR DISK-ERROR !   ;
:  WBIOS   3 SETUP INT13 >R INT13 R> OR DISK-ERROR !   ;
:  BIOS-IO ['] RBIOS IS READ-BLOCK  ['] WBIOS IS WRITE-BLOCK  ;
:  SET-IO               / SET UP TO READ RAW, WRITE TO DOS
    [ DOS ]   FILE-IO
    [ FORTH ] ['] RBIOS IS READ-BLOCK ;

:  DO-COPY              / COPY 31 DAYS WORTH OF DATA
    279  0  DO
            I  369 +   / DATA STARTS ON SECTOR 18 OF DATA DISK
            13 EMIT I 5 .R  / (TWO SECTORS/K, 1K/SCREEN )
            I  COPY DISK-ERROR @
            KEY? OR IF QUIT THEN LOOP ;

:  PROMPT               / WAIT FOR THE USER TO BE READY
    ." INSERT DATA DISK IN DRIVE B:, DOS DISK IN DRIVE A: " CR
    ." PRESS ANY KEY WHEN READY. " CR  KEY DROP ;

:  DO-IT
    CR PROMPT           / GET THE DISKS IN PROPERLY
    DEFAULT             / OPEN THE OUTPUT FILE
    SET-IO              / SET UP TO READ DATA, WRITE TO DOS FILE
    DO-COPY             / TRANSFER THE DATA TO THE FILE
    CR ." TRANSFER COMPLETE"
    BYE   ;             / AND EXIT
```

APPENDIX C

CONVERT FORTRAN COMPUTER PROGRAM

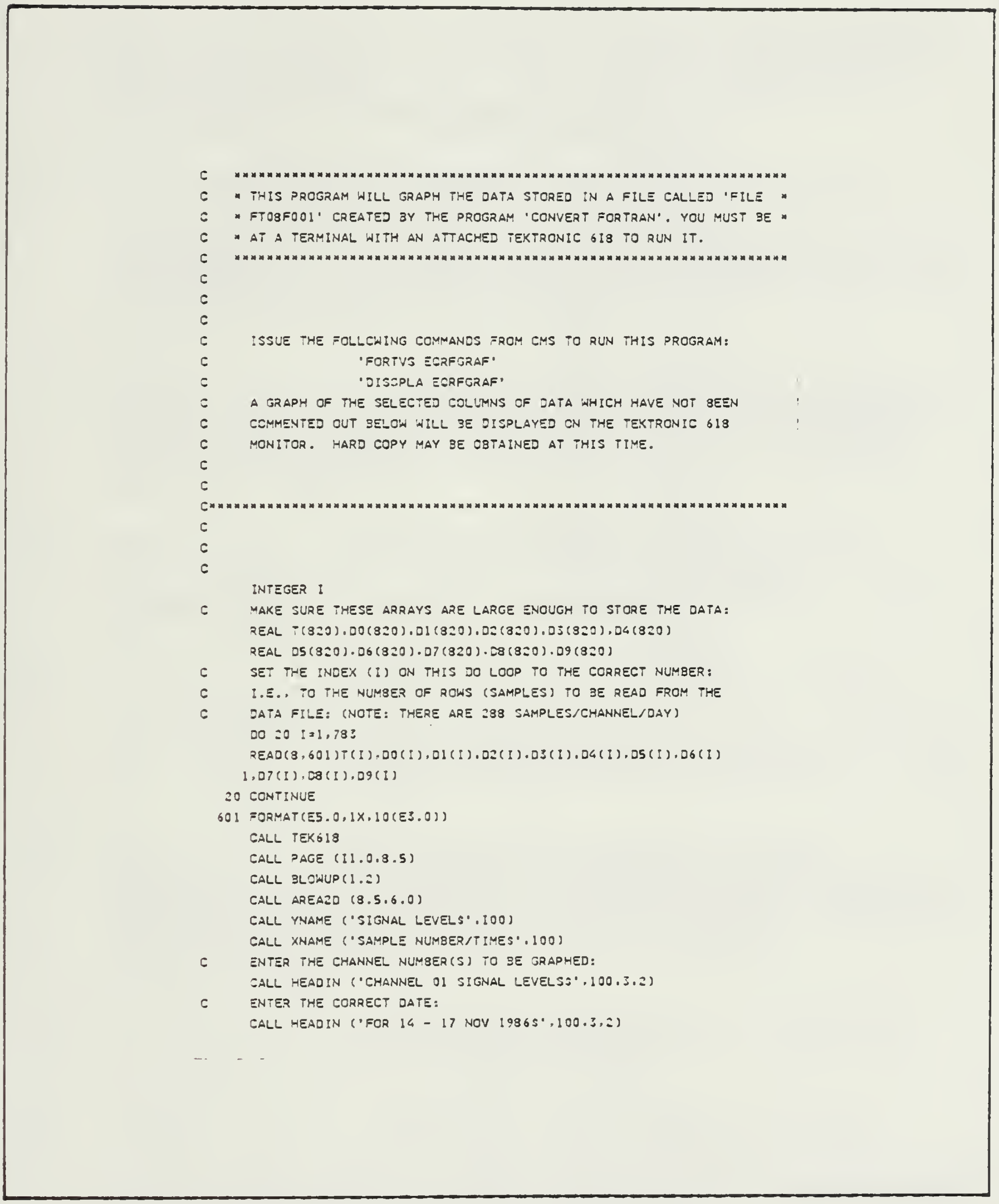


```
C   ****************************************************************
C   * THIS PROGRAM WILL CONVERT THE DATA FILE THAT WAS TRANSFERRED *
C   * FROM AN IBM PC TO THE MAIN FRAME INTO A NEW FORMAT.  THIS    *
C   * NEW FORMAT WILL ALLOW FOR PLOTTING OF THE DATA USING DISSPLA.*
C   ****************************************************************
C
C
C
C     THE DATA ARRIVES ON THE MAIN FRAME IN THE FILE 'ACQUIRED DATA'
C     FROM THE PCDOS FILE CALLED 'ACQUIRED.DAT' AS APPROXIMATELY 3900
C     LINES OF DATA. THE 30 CHARACTER SEGMENTS OF DATA (10 CHANNELS OF
C     DATA WITH 3 CHARACTERS PER CHANNEL) ARE WRITTEN INTO THE 80
C     CHARACTER PER LINE FILE, SEPARATED BY TWO DIGIT TIME STAMPS (I.E.
C     01,02,03,04, OR 05).  THIS PROGRAM READS THE 30 CHARACTER
C     SEGMENTS ONE BY ONE OUT OF THE ACQUIRED DATA FILE AND ARRANGES
C     THEM IN A SEQUENTIAL FILE.  IN THIS WAY THE DATA IS AVAILABLE
C     IN AN EASILY DISCERNABLE FORM FOR THE USER AND ALSO IS READILY
C     GRAPHED.  MINOR ADJUSTMENTS IN THIS PROGRAM MAY BE NECESSARY
C     TO ACCOUNT FOR VARIATIONS IN THE MICRO TO MAIN FRAME TRANSFER
C     PROCESS.  THE POSSIBLE CHANGES ARE NOTED WITHIN THE PROGRAM.
C     FOLLOW THE STEPS OUTLINED BELOW TO ARRANGE THE DATA IN A FORMAT
C     FOR USE IN A PROGRAM TO GRAPHICALLY DISPLAY THE DATA:
C
C
C     STEP 1: PUT THE DATA IN THE FILE 'ACQUIRED DATA' INTO A FILE
C             CALLED 'FILE FT08F001' AFTER ANY NON ESSENTIAL
C             INFORMATION THAT WAS TRANSFERRED HAS BEEN EDITED OUT.
C     STEP 2: MAKE ANY NECESSARY CHANGES IN THIS PROGRAM, ESPECIALLY
C             TO THE "ISTART" PARAMETER.
C     STEP 3: RUN THIS PROGRAM AND SAVE THE NEWLY FORMATTED DATA
C             FILE BY ISSUING THE FOLLOWING SEQUENCE OF COMMANDS AT
C             THE APPROPRIATE TIMES:
C                  'FORTVS CONVERT'
C                  'RECORD ON'
C                  'LOAD CONVERT(START'
C                  'RECORD OFF'
C             TEMPORARILY STORE THIS DATA IN ANY FILENAME,FILETYPE.
C     STEP 4: ERASE THE FILE CALLED 'FILE FT08F001' CREATED IN STEP 1.
C     STEP 5: CHANGE THE NAME OF THE FILE CREATED IN STEP 4 INTO
C             'FILE FT08F001'.
C     STEP 6: GO TO THE FILE 'EQRFGRAF FORTRAN' AND PROCEED.
C*******************************************************************
```

```
      INTEGER I,J,K,L,ISTART
      CHARACTER*1 A(160),B(30)
C     NOTE: SEE INSTRUCTIONS ON HOW TO SET THIS PARAMETER "ISTART":
      ISTART = 16
      L = 1
 5    READ(8.10.END = 1000) A
 10   FORMAT(80A1/80A1)
      J=0
      DO 20 I = ISTART+1,30
 20   B(I) = A( I -ISTART)
      WRITE(6,30) L,B
 30   FORMAT(T2,I5,1X,30A1)
      L = L + 1
      J = 32 - ISTART
      DO 50 K = 1,4
      DO 40 I = 1,30
 40   B(I) = A(I+J)
      WRITE(6,30) L,B
      L = L + 1
 50   J = J + 32
      DO 60 I = 1,ISTART
 60   B(I) = A(160 - ISTART + I)
      GO TO 5
 1000 CONTINUE
      RETURN
      END
```

APPENDIX D

EQRFGRAF FORTRAN COMPUTER PROGRAM



```
C   ****************************************************************
C   * THIS PROGRAM WILL GRAPH THE DATA STORED IN A FILE CALLED 'FILE  *
C   * FT08F001' CREATED BY THE PROGRAM 'CONVERT FORTRAN'. YOU MUST BE *
C   * AT A TERMINAL WITH AN ATTACHED TEKTRONIC 618 TO RUN IT.
C   ****************************************************************
C
C
C
C     ISSUE THE FOLLOWING COMMANDS FROM CMS TO RUN THIS PROGRAM:
C                 'FORTVS EQRFGRAF'
C                 'DISPLA EQRFGRAF'
C     A GRAPH OF THE SELECTED COLUMNS OF DATA WHICH HAVE NOT BEEN
C     COMMENTED OUT BELOW WILL BE DISPLAYED ON THE TEKTRONIC 618
C     MONITOR.  HARD COPY MAY BE OBTAINED AT THIS TIME.
C
C
C******************************************************************
C
C
C
      INTEGER I
C     MAKE SURE THESE ARRAYS ARE LARGE ENOUGH TO STORE THE DATA:
      REAL T(820).D0(820).D1(820).D2(820).D3(820),D4(820)
      REAL D5(820).D6(820).D7(820).D8(820).D9(820)
C     SET THE INDEX (I) ON THIS DO LOOP TO THE CORRECT NUMBER:
C     I.E., TO THE NUMBER OF ROWS (SAMPLES) TO BE READ FROM THE
C     DATA FILE: (NOTE: THERE ARE 288 SAMPLES/CHANNEL/DAY)
      DO 20 I=1,783
      READ(8,601)T(I),D0(I),D1(I).D2(I).D3(I).D4(I).D5(I).D6(I)
     1,D7(I),D8(I),D9(I)
   20 CONTINUE
  601 FORMAT(E5.0,1X,10(E3.0))
      CALL TEK618
      CALL PAGE (11.0.8.5)
      CALL BLOWUP(1.2)
      CALL AREA2D (8.5.6.0)
      CALL YNAME ('SIGNAL LEVELS'.100)
      CALL XNAME ('SAMPLE NUMBER/TIMES'.100)
C     ENTER THE CHANNEL NUMBER(S) TO BE GRAPHED:
      CALL HEADIN ('CHANNEL 01 SIGNAL LEVELS$',100.3.2)
C     ENTER THE CORRECT DATE:
      CALL HEADIN ('FOR 14 - 17 NOV 1986$',100.3,2)
```

```
C     ENTER THE PROPER X AN Y RANGES OF THE GRAPH:
      CALL GRAF (5,50,783,100,20,360)
      CALL GRID(1,1)
      CALL SPLINE
C     ENTER THE ENDING DATA PARAMETER ON THE CHANNEL(S) SELECTED:
C     CHANNEL 1:
      CALL CURVE (T,D0,783,0)
C     CHANNEL 2:
C     CALL CURVE (T,D1,783,0)
C     CHANNEL 3:
C     CALL CURVE (T,D2,783,0)
C     CHANNEL 4:
C     CALL CURVE (T,D3,783,0)
C     CHANNEL 5:
C     CALL CURVE (T,D4,783,0)
C     CHANNEL 6:
C     CALL CURVE (T,D5,783,0)
C     CHANNEL 7:
C     CALL CURVE (T,D6,783,0)
C     CHANNEL 8:
C     CALL CURVE (T,D7,783,0)
C     CHANNEL 9:
C     CALL CURVE (T,D8,783,0)
C     CHANNEL 10:
C     CALL CURVE (T,D9,783,0)
      CALL ENDPL (0)
      CALL DONEPL
      STOP
      END
```

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